STANDARD CONSTRUCTION METHODS

UNDERWOOD

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Books by

G. UNDERWOOD

STANDARD CONSTRUCTION METHODS

ESTIMATING CONSTRUCTION COSTS

STANDARD CONSTRUCTION METHODS

BY

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Construction Engineer
thor of "Estimating Construction Costs"

SECOND EDITION
TENTH IMPRESSION

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To My Wife

LENORE UNDERWOOD

This Book Is Dedicated

PREFACE TO THE SECOND EDITION

Many up-to-date features have been added to the second edition of this book. The chapters relating to various phases of construction work have been enlarged, the additions consisting almost entirely of information on technical details which can be acquired only by actual contact with the work.

Forms for concrete floors are now discussed in the chapter on concrete. A generous number of figures are supplied showing in detail the several methods usually followed in constructing concrete floors in fireproof buildings.

Leaks and seepage through concrete floors and walls of substructures are given careful attention in this chapter. Several pages are allotted to a discussion of various chemicals which are useful in plugging leaks and speeding up the set of portland cement.

A discussion of leaks in brick buildings has been included. The cause and origin of seepage is analyzed and thoroughly treated, and methods are outlined for stopping any seepage which occurs.

House moving is an additional subject which will prove interesting to many readers. Several pages of text and illustrations have been provided to set forth the skilled knowledge required in this branch of rigging work.

Towers and elevators for hoisting construction materials in building work have been discussed in minute detail. The designs and methods of constructing several types of towers are described from a practical point of view.

The chapter devoted to pipework has been augmented by additional information relating to the art of cutting tight pipe threads, and instructions are given for successfully bending steel pipe.

Methods of trussing the interior bracing of wide cofferdams are given ample treatment, and useful information is furnished for building drains and sumps and for pumping water.

Ornamental plaster-casting work is described in conjunction with many other items which have been added to the chapter devoted to plastering.

Many other additions have been made which it is not possible to enumerate in this preface. The practical usefulness of these additions will be of special interest to engineers and construction men.

G. UNDERWOOD.

NEW YORK,
October, 1931.

PREFACE TO THE FIRST EDITION

This book is intended to serve the needs of men engaged in actual construction work. It is the first comprehensive book of its kind dealing with standard construction methods. Very little has been published concerning actual construction methods and that which has been published is either so lacking in exactness of information or is so narrow in scope as to render it useless as far as the ordinary construction man is concerned.

Primarily the book is intended for the use of construction superintendents and others upon whom the responsibility of getting things done may rest. It covers a wide field. This is essential if it is to be useful to men who are expected to have a wide general knowledge of construction work.

The author has endeavored to make simplicity and preciseness the outstanding characteristics of the book. He has adhered to simple principles and has described only such methods as he has found to be the most useful in the ordinary run of work. Descriptions of stunts and unusual methods have been carefully avoided.

In planning the book, each subject has been visualized from the standpoint of a construction superintendent and the usual and most up-to-date way of doing the work has been described. Sufficient other information has been given in each chapter to make clear the science of the subject. The following classes of work have been arranged in chapters following each other in accordance with the sequence of operations usually followed in construction projects. Especial attention is called to the chapter on Erection and Rigging.

G. UNDERWOOD.

PLAINFIELD, N. J.,
May, 1927.

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STANDARD CONSTRUCTION METHODS

CHAPTER I

ORGANIZATION AND EQUIPMENT

Construction Methods.—Construction operations may be most successfully performed by selecting simple and direct methods for doing the work. By many years of practical application, each branch of the construction profession has developed certain methods of doing its work that have proved their superiority over other ways of doing the same thing. These methods have become standard methods and should be employed wherever possible.

The nature of a proposed undertaking and the location of it may each control the general scheme of doing the work, and the character of the construction plant and equipment needed may vary widely. A building operation in a thickly populated city does not permit the same latitude in handling the work as does the construction of an industrial plant on the outskirts of the same city.

Organizing.—When a constructor visits the site of a proposed undertaking for the purpose of starting active operations, it is necessary for him to turn his attention at once to obtaining labor and materials. The first things to which his consideration should be directed are materials for a construction office and storage sheds, some workmen, a telephone service, and a water supply.

The materials needed will have to be obtained from local dealers and for this purpose credit and charge accounts should be arranged with material supply companies, hardware dealers and others. If the work is to be done under union conditions, the first skilled labor needed may be most easily obtained by communicating with the business agent of the local union. In any case, inquiry in the neighborhood, advertising in the local papers, or recourse to an

employment exchange will usually provide the four or five men which generally are all that are required for starting the work. The attention of desirable men will be attracted if a news item is published in the local newspapers saying that the work has been started.

After the first few men are at work, applicants will soon present themselves in numbers exceeding requirements. A book may be kept in which names of applicants and addresses are listed, together with the occupation and some short note of identification. As the work expands and more men are needed, they may be notified by mail that positions are available for them.

Arrangements for a water supply and telephone service should be attended to immediately upon starting the work. To provide water, the nearest water main will have to be tapped and piping connections will have to be made leading to a water meter placed just inside the property lines. This work is usually done by the town water department and includes the placing and furnishing of the meter. The telephone service is procured by application to the telephone company and hardly deserves any mentioning beyond the statement that the service should include an outside bell large enough to be heard at all parts of the work and, also, that it will usually require a period of a week or two after the application has been made before the installation of the service is an accomplished fact.

TEMPORARY STRUCTURES

General.—Labor and supplies having been arranged for, everything is in shape to begin the construction of some of the temporary structures. An office and a tool house are the first buildings needed; later a storage house for cement and other materials, access roads, and, on large undertakings, shanties for blacksmith, pipe fitters, and electricians and such additional storehouses as may seem necessary, may be constructed.

Before starting construction, considerable thought should be given to the location of these buildings and questions of size and design should be decided upon. The locations selected for the buildings should be chosen so as to be the most advantageous for the purpose of each structure, and the design should be determined upon with consideration for matters of suitability and economy. The manner of constructing temporary structures may vary according to individual ideas and with the requirements

of each particular undertaking, but it is thought that the suggestions which follow will satisfy the conditions met with on most construction jobs.

Figure 1 represents an hypothetical plan of an industrial plant that is to be constructed. It is assumed for the purpose of illustrating the most-preferable locations for the temporary office, the tool house, and the cement shed.

Construction Office.—The office should be situated, if possible, just outside the zone of actual construction so as to be central in two directions at least to all parts of the work. It should be located preferably along the road leading into the property and over which all vehicles bearing supplies will pass, as well as all

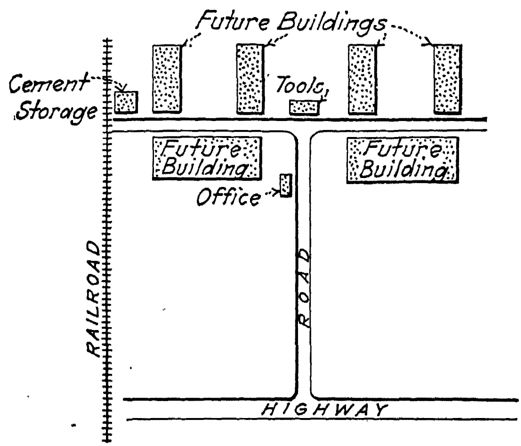


FIG. 1.—Plan of an industrial plant.

persons visiting the work for purposes of business. Such a position is most convenient, as it will be necessary for someone at the office to sign for the receipt of supplies and give directions for placing and unloading them. Another advantage of such a location is that it prevents applicants for employment and other persons from entering the region of active operations.

The office should be of frame construction and should contain at least two rooms. One of these rooms will be necessary for the exclusive use of the superintendent and his clerical force. The second room will be found useful during the early period of the work, before a tool house is built, for the use of carpenters and foremen and for the safe keeping of carpenters' kits, tools, and supplies. Later, this room may be used to house the clerk, time-

keeping staff, and for the use of foremen. Figure 2 shows a sketch and cross-section of a construction office which will be found to fulfil all ordinary requirements. A good width for such an office is 14 feet, as this width gives sufficient space inside the building and conforms to a standard length of floor joist which is obtainable in all lumber yards. Two rooms, each 14 by 14 feet, will result in a structure which is 14 by 28 feet in plan.

A peak roof is desirable, insuring good ventilation, and should be covered with roofing felt laid over ⅞-inch roof boards. For

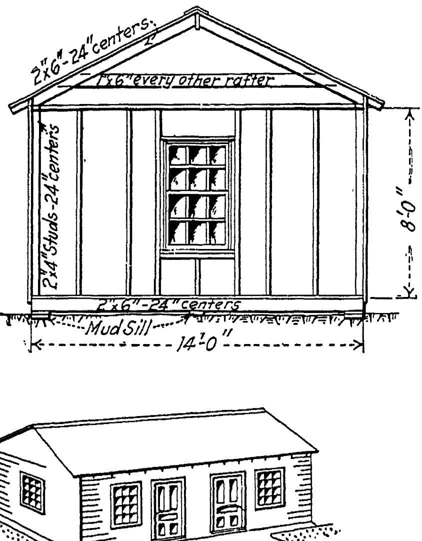


FIG. 2.—Construction office.

sheeting the sides of the office, matched boards, either shiplap or tongue and groove, may be used advantageously, or the sheeting may be done with square-edged boards or novelty siding, according to the relative demands of economy and appearances. The sides, if sheeted with matched boards, may be simply painted for the summer months and covered later with roofing felt as a protection from cold weather and rain. Square-edged boards will shrink, no matter how closely laid, and will require a covering of roofing felt at all seasons. Novelty siding or beveled siding may be used, and they present a very neat appearance when in place

but they require corner strips and are more expensive than ordinary boards for both material and labor.

Entrance doors should be provided for each room. They should be located in the side facing the work or the road. A communication door may be placed in the dividing partition between the two rooms. It will pay to order mill-made doors and frames of stock pattern about 3 feet wide and of cheap pine material. There may be three windows in each room. The

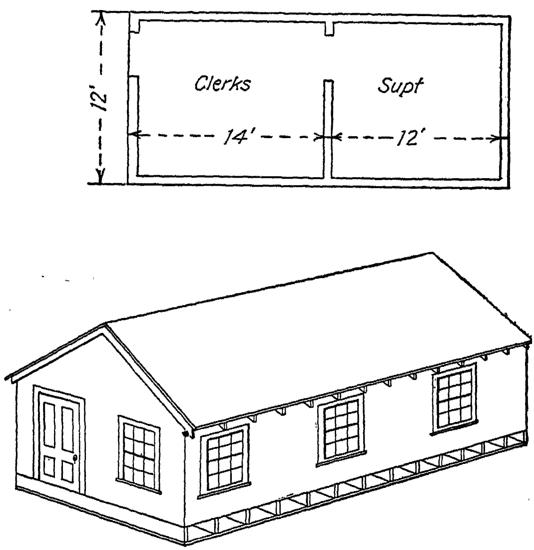


Fig. 3.—Construction office.

windows like the doors should be preferably mill made and of stock sizes. Windows containing 12 lights and about 32 inches wide are suitable. When framing the window openings, fix the height of the stools so that the heads of the windows and doors will be at the same height. This will give the exterior of the office an orderly appearance. The windows should be provided with catches and sash weights. For the door hardware, order 4-inch butts and one rim lock for each door and also an additional snap lock for each of the entrance doors. Unless the inside of the building is to be sheeted, no inside casings need be ordered for the doors and windows.

Figure 2 shows details of construction and sizes and spacing of framing lumber. When starting to build the office, the site

should be leveled and the mud sills laid flat upon the ground and made level all the way around. The mud sills may be cheaply formed of 2-by-6 or 2-by-8 plank doubled and extending around all four sides of the building. The floor joists rest with their ends bearing upon the mud sills and are sheeted, preferably, with tongued and grooved floor boards ⅞ inch thick. After the carpenter work has been completed, unless the sides of the building are to be covered with roofing felt, the outside of the building should be given two coats of oil paint or creosote stain. The colors most practical to use are dark green, dark red, or drab.

A good design for a construction office is represented in Fig. 3. There is an entrance door in one end. A partition divides the

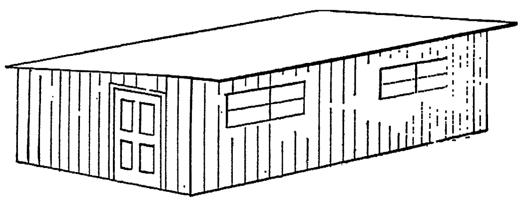


FIG. 4.—Portable shanty.

building into two rooms. The front room can be assigned to the timekeeper and other clerks. The rear room can be reserved for the superintendent's use. The building can be made portable by making it in sections and fastening the sections together with ½-inch bolts and with hooks and eyes. A saving in labor and lumber may be gained by installing the boards vertically. The sheeting of the sides is then self-supporting. The boards should be nailed to a framework of 2-by-4 lumber, the vertical studs being spaced about 5 feet apart.

A portable shanty suitable for a small office is shown in Fig. 4. The sheeting boards are nailed vertically on a frame of 2-by-4 lumber. The 2-by-4's are placed flat against the sheeting and save space in that position. The building can be made 12 feet wide and 20 feet long. The floor should be made in two sections. The roof and sides can be in one piece or divided, as may be desired. The shanty can have two doors, one in each end, if there is a center partition, or a single entrance door can be made in the side. The sections of the building should be fastened together with hooks and eyes.

Tool House.—The tool house should be centrally located with reference to the region requiring the greatest amount of running back and forth of workmen for tools and supplies. Like the office, it should be located along one of the roads giving access to the work, but even more centrally located than the office (see Fig. 1) as, excepting for deliveries, it will be visited only by those desiring tools or bolts or similar supplies, which may be urgently needed at times.

The tool house does not need to be so neat in appearance as the office, but should be constructed with strong flooring and with

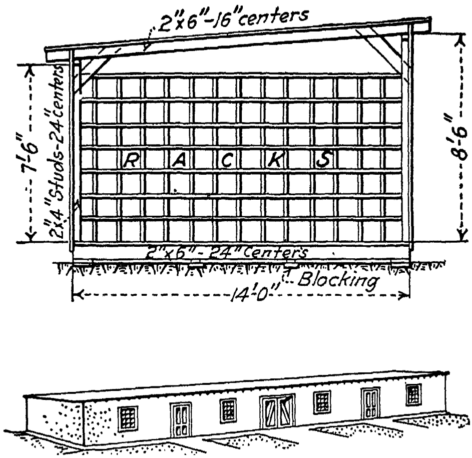


Fig. 5.—Tool house.

tight sides and roof. A building square in plan is not so good as one whose length is several times its width. A tool house (Fig. 5) which is comparatively long and narrow in plan will have better lighting from the windows and, what is equally as important, will allow ample entrances to be provided. Then bulky supplies, such as rope, kegs of nails, and barrels, will not have to be moved over previous deliveries but may be easily unloaded and will be readily available when required. A width of 14 feet is good and a length of 80 feet is not excessive for a fair-sized construction operation.

The tool house may be built with a flat roof having a pitch of 1 foot downward to the rear so as to shed the drainage from the roof away from the principal entrances. By making the studs 8½ feet long in front and 7½ feet long in the rear of the building,

studding material ordered 16 feet long will cut up conveniently and will give ample height to the roof. The same considerations that held in choosing the materials for sheeting and covering the sides and roof of the office hold for choosing those for the tool house, except that cheaper materials may be favored.

Both ends of the tool house should be entirely occupied by racks for the storage of small tools, bolts and the like and should be provided with a counter across the entire width. Windows in these ends are not necessary. The side of the tool house facing the roadway should contain several entrance doors with windows alternating. A good arrangement is to place a door about 3 feet wide near each end with a double door in the center for entrance of bulky objects. In the side not facing the roadway, one doorway in the center of the building will be sufficient, the remaining spaces should be provided with windows. Cheap mill-made pine doors and windows similar to those used for the office will prove satisfactory, as the tool house deserves good lighting.

In building the tool house, a solid level fill should be made, elevating the mud sills slightly above the surrounding surface of the ground, having first removed all or the greater part of the top soil. This latter precaution is necessary, as the tool house floor will often become very heavily loaded in spots and the mud sills will be pressed downward unequally into the soft soil, particularly during periods of rain or thaw. This would result in a sagging floor and roof.

Figure 5 is a sketch and cross-section of a tool house which is suitable for a large operation and should be found satisfactory in every way. The sills are made of 2-by-6 or 2-by-8 plank doubled and laid level and flat upon the ground. They extend completely around all sides of the building and are supplemented by one or two additional lines of plank sills running lengthwise of the structure. These are spaced so as to reduce the span of the floor joists and give a practically solid floor. These additional planks may be laid singly and need not be leveled as carefully as the outside sills. The floor joists can be brought easily to a bearing by the use of blocking and a few wedges. The sketches, shown in Fig. 5, give sufficient details to make clear the general idea of construction, but it is well to add that while ordinary ⅞-inch boards may be used for flooring, a heavier thickness will give better service as heavy objects when deposited roughly will break through an ordinary ⅞-inch floor.

The knee braces shown should not be omitted, as the wind will exert an enormous pressure on a long narrow building in an exposed location and will force the sides out of plumb if the bracing is omitted. The racks at the ends of the building for storage of small tools and bolts should completely fill the entire area from floor to roof and should be divided into compartments about 12 inches square. No framing lumber need be used in constructing these racks as they may be built entirely of ⅞-inch boards. The shelves are formed by horizontal boards supported by short pieces of board cut in between them, which

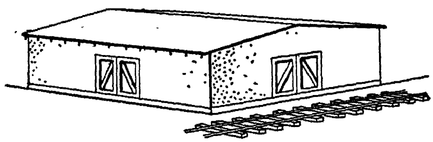


FIG. 6.—Cement-storage shed.

serve as supports and at the same time form the sides of the compartments.

Cement Shed.—The chief requirements of a cement shed are to provide ample storage capacity and to give thorough protection to the cement against dampness.

In the shed, shown in Fig. 6, other materials which should be protected may also be stored, such as maple flooring, lime, plaster, asbestos, and the like.

The location of the cement shed should be chosen with regard to economy in handling the cement. Cement, when ordered in quantities of 173 barrels or 692 bags and over, called carload lots, is shipped from the mills by railroad. Consequently, if there is a railroad siding on the property, the cement shed should be placed close to it, so that the unloading of the cement from the cars to the shed may be accomplished economically; preferably, by means of chutes. If no railroad siding is arranged for on the property, the cement shed should be placed beside a road or where a short road can be built to it. If possible the shed should be located close to the place where the greatest amount of cement will be used, so that the cement may be distributed over the work by short hauls in wheelbarrows. Often this will be impossible and much of the transportation from the shed will have to be done by trucks.

A building which is square in plan will be suitable and will be the most economical per cubic foot of capacity. In determining the size of the storage which is necessary, it is well to remember that an ordinary freight car in which cement is shipped is about 8½ feet wide by 30 feet long and that the cement can be piled in the cement shed to twice the height it is piled in the cars. Cement should not be piled over 10 bags high. It only remains to make an assumption as to how many carloads of cement will be stored in the shed at any one time.

A peaked roof with a slight pitch is suitable, 1 inch to the foot is sufficient. The cement shed is usually constructed in the

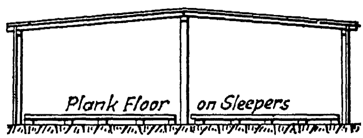


FIG. 7.—Section through cement-storage shed.

cheapest manner possible, using the cheapest boards for sheeting the roof and side walls. A good quality of roofing felt, however, should be used for covering both the roof and the side walls. Studs in the sides may be spaced between 3 and 4 feet apart. No windows are necessary, sufficient light being provided when the doors are opened. Wide double doors should be placed in at least three sides of the building to make all parts of the shed accessible for receiving and distributing the cement. The doors should always be arranged to open outward.

Unlike most other buildings, the cement shed should be constructed with the floor entirely separate from the sills, so that the inevitable settlement which will occur in the floor due to the enormous weight of the cement will not affect the rest of the structure. Figure 7 indicates the construction that may be used for a cement shed.

The site of the building should be covered with a fill, so as to elevate it above the general surface of the ground. For sills use 2-by-6 planks leveled and laid flat on the ground and nail the bottoms of the studs to these. The floor should be constructed of rough 2-inch planks laid on sleepers of any cheap and convenient material, resting directly on the ground. The floor planks should not be nailed to the sleepers and may be 2 by 6's.

Access Roads.—The planning of the access roads to serve the construction work is easily accomplished if the ground to be

traversed is firm and dry. Roads may then be built cheaply almost anywhere within the property, and will require only a small amount of grading for their construction. The road leading into the work should be central with branches leading to important sections and running close to the principal structures so as to facilitate handling of materials. Often the same positions selected for permanent roadways, as shown on the plans for the completed plant, may be used in part for arranging the locations of the roads serving the construction operations.

Where the ground is soft or swampy, the construction of roads becomes a matter of some importance. Materials must be provided for their construction and also for their maintenance. The cheapest and best road material to use on soft ground is bituminous-coal cinders. When these are thrown directly upon soft or marshy ground, they will gradually work downward into the soil and need constant replenishing. To avoid this result, salt-hay or straw should be spread upon the surface of the ground crosswise to the axis of the road. The cinders or gravel, as the case may be, should be placed on this foundation. The hay should be spread over a space wider than that which will be occupied by the cinders, so that the load from the traffic may have a greater bearing on the underlying soil. Unless subdrains are provided for the roads, which would be unusual, the traffic, after a rain, will destroy the surface of the road and lead to miring of trucks in the ruts and to congestion of traffic, unless provision is made for vehicles to pass each other. To give good service, the top of the access road should be built at least 1 foot above the surface of the ground. This will usually insure satisfactory drainage.

On small undertakings or where it is inconvenient and costly to provide other materials, a roadway formed of 3-inch planks laid crosswise of the road will prove satisfactory.

Water Supply.—A supply of water is needed for drinking, for steam boilers, for mixing concrete, and for other purposes. To this end, a comprehensive plan for supplying water to all parts of the work should be laid out. The water meter must be inclosed in a wooden box made large enough so that the meter can be surrounded with straw or other materials to prevent freezing. A supply of steel pipe must be provided in sufficient quantity to deliver the water to all points where it is likely to be used.

On a large building operation, the main line leading from the meter to the center of the work, as well as any principal lines branching from it, may be made of 2-inch pipe. The small branches leading to individual localities may be made of ¾-inch pipe. As it is impossible to foresee just where it will be most convenient to run the small branch lines, it is well to put a tee in the 2-inch main lines about every 100 feet with occasional flanged unions. The tee may be 2 by 2 by ¾ inches, provided with a ¾-inch plug or a 2- by 2- by 2-inch tee may be used with a 2- by ¾-inch bushing and ¾-inch plug. A 2-inch valve should be placed just beyond the meter so the entire supply can be shut off. Similar valves should be placed along the main 2-inch lines about 300 feet apart. Each ¾-inch branch line should also be provided with a valve close to the 2-inch line.

For many construction operations, a 2-inch pipe line is larger than will be needed and 1½ inches or smaller may be used, but nothing smaller than ¾-inch pipe should be used for any purpose. Ordinarily, temporary water pipes are laid on top of the ground. While this answers every purpose with moderate temperatures, during freezing weather such pipe lines will need better protection. To guard against freezing, the main lines should either be placed below ground or covered. The small lines which are in daily use should be disjointed and water drained from them at the close of each day's work.

MECHANICAL EQUIPMENT

General.—The problem of selecting the proper mechanical equipment to be used is mainly one of moving materials from one place to another, either to place them in their permanent position in the completed structure or to remove them from the premises. The advantage to be derived from the use of any appliance can be judged by the convenience and economy with which this moving is accomplished. The question of economy is largely one of capacity to perform work, balanced against the cost of purchase or rental, and the cost of placing in position and subsequent removal. A machine or an apparatus whose purchase cost seems prohibitive can usually be rented at a daily or weekly rate. The cost of installation and of removal, after its work has been finished, will be somewhat fixed in amount and will have to be estimated.

The capacity of an appliance to perform work will depend largely on the abilities of the organization working with it, while the total quantity of work that can be performed by the apparatus and the amount of it at any one location will furnish the data by which the economy of using it may be computed.

While it is the purpose of this chapter to discuss the mechanical equipment used for construction work such as machines, tools, and appliances generally, the matter of computing costs in detail for each method of performing work is out of the province of this volume; but in general the computation of cost of doing work by any machine may be outlined as follows, the figures being assumed for illustration:

		For Period of Use
Purchase or rental		$400
Placing and removal		100
Supplies		25
Total operating labor		900
Quantity of work	1000	$1425
		$1.425 per unit of work

The first three items may be either ascertained or approximated even by persons possessing only a limited experience, but the last item is one that can be estimated accurately only by comparison with results obtained on previous work under similar conditions and constitutes information which is usually carefully guarded. For this reason, it is good policy to keep cost records of all work that is performed and to keep the records in such a manner that they may be used at some future time when needed for estimating purposes.

Pick and Shovel.—The simplest tools for excavation are, of course, a pick and a shovel. All other means of earth removal must prove their economy by comparison with this simple method of manual labor. Excavation done by other apparatus such as steam shovels, scrapers, and the like is never completed until trimmed to final line and grade by the shovel and the pick.

Shovels are made in various sizes and weights of blades, which are designated by numbers. They are also classed as to the shape of the end of the blade. For ordinary digging, a round-pointed shovel should always be used but where the shoveling is to be done on a platform or flat surface, a square-pointed shovel should be

employed. For ordinary digging, a No. 2 shovel will prove both light and efficient. The standard length for a shovel from the tip of blade to the end of handle is 3 feet and this fact is often useful in making rough measurements of depths while excavating. Long-handled shovels with either round- or square-pointed blades can be procured which are adapted to various purposes such as excavating deep holes, the areas of which are too small to admit a workman, or digging a trench in tenacious earth when it is desired to deposit the excavated material back from the edge of the trench.

Drag Scraper.—The drag scraper drawn by two horses is a useful and economical tool for excavating earth where it is to be moved only a short distance. It is most useful for removing top soil and in grading operations. It is necessary to prepare the ground for the drag scrapers by ploughing and, although the expense of digging and loading with shovels is avoided, the cost of transporting the excavated material in the scrapers is considerable. A double team is usually necessary to operate a drag scraper and when the area to be excavated is so small that only one or two teams can be worked, it will often be found less expensive to excavate with pick and shovel and to transport the materials in wheelbarrows or carts.

When the scrapers have to be dragged a distance of about 100 feet over the ground, much of the load will be spilled out of the scoop and the surface of the ground over which it is dragged gradually takes the form of a series of waves which grow larger and larger, causing the scoops to tilt and to lose increasing portions of their contents. When this occurs it is necessary to use the scoops to level off this uneven surface. The spilling of the contents of the scrapers together with the time consumed in the hauling makes 150 feet the economic limit of haul for drag scrapers.

Wheeled Scraper.—The wheeled scraper is advantageous to use where the length of haul exceeds the distance for which the drag scraper can be used with economy. The wheeled scraper however, can be used only for handling very loose material like sand or cinders, as the scoop has a long cutting edge and it requires the combined efforts of a double team pulling it and two men holding the handles to fill the scoop even when the material is in loose piles. The scoop, however, when loaded is hung from the axles in such a manner that none of its contents is spilled

during transit and it is easily dumped by one man at the end of the haul. The wheeled scraper is not so simple in construction as the drag scraper. It is equipped with wheels and a pole for double teams. The purchase cost is appreciable and is an item to be considered in relation to the amount of work to be done. The economic length of haul for this type of scraper is usually assumed to be 500 feet.

Steam Shovel.—A steam shovel is economical to use where a large volume of earth is to be removed. In most cases, the advantage of employing a steam shovel over other methods is apparent at once; in others, by reason of cost of rental, transportation, and operation it may be necessary to prepare estimates showing relative costs. Generally, however, a steam shovel of the revolving type is economical to use wherever there is sufficient area for it to be operated. Steam-shovel work, together with hauling and trucking, is frequently sublet to contractors making a specialty of this work.

Revolving Shovel.—The revolving type of steam shovel is the one which is most generally useful, as it is very adaptable to all conditions. It is quickly and cheaply transported over roads, furnishing its own traction without the use of rails and may be used for a wide variety of excavation, removing earth in deep wide excavations, in shallow digging for roads, or in trench work.

The entire working mechanism of the shovel above the truck frame revolves in a complete circle, enabling it to load trucks in any position within this circle. It may also be moved laterally so as to excavate a wide area, which is an advantage over the steam shovel operating on rails, for the track shovel is restricted in the width of cut by the position of the track and the reach of the dipper. It possesses another advantage over the track shovel, in that it is able to be worked downward and upward out of the excavation, at the completion of the work, at much steeper grades. Only one operator and one helper are necessary to operate this shovel.

Track Shovel.—The track steam shovel is employed principally on the largest excavating operations. It is made in various sizes equipped with scoops of different capacities. It is chiefly adapted to heavy work where shovels of large size are required and where large quantities are to be excavated in one place as in hillside cuts or railroad work. This type of steam shovel is built to operate on a track made in short sections formed of steel

rails with ties attached. In transporting the shovel over highways, these sections of track have to be taken up successively as the shovel is moved ahead, the section of track in the rear of the shovel being unbolted and carried to its new position in front. This, of course, is a slow and costly method of transportation, but, when the shovel is to be used for a long time and large quantities of material are to be handled, the expense becomes insignificant.

The track shovel requires for its operation two operators and one helper. As the shovel proceeds into the excavation, full-length rails may be laid in the rear of it, forming a track, so that when it is desired to change the direction in which the shovel is working and to widen the excavation, the shovel may be run back on the rails and the forward end of this track may be thrown over in a curve in the direction desired. In this type of shovel the housing containing the boiler remains fixed in position, only the dipper stick with the dipper revolving. As it is impossible for the dipper to revolve in a complete circle, trucks to be loaded must be stationed on either side of the track opposite the forward end of the shovel.

This type of shovel is used largely when the excavated materials are to be transported in cars running on tracks. The material tracks must be laid parallel to the track supporting the shovel and must be moved in conjunction with the shovel track when the latter is shifted. In digging below grade, this type of shovel has to proceed downward at a slight slope and when operating has to be supported sideways by a mechanism which prevents the great weight of the loaded scoop when swung to one side from overturning the shovel.

Drag-line Excavator.—The drag-line excavator, while not so commonly in use as the steam shovel, fills an important field of usefulness of its own. The whole body above the trucks revolves in a complete circle. The drag line excavates by dragging its scoop in the rear toward the machine instead of digging in front as the steam shovel does. The boom is always of long length and excavated material can be cast to one side at a great distance. This feature makes it particularly useful in digging canals and aqueducts where the earth can be piled clear of the side of the cut.

The drag-line excavator is always operated from the surface of the ground and is particularly useful for digging drainage ditches in which the water may be allowed to flow into the excavated trench without interfering with the operation of the machine. It

is also possible to equip the drag-line excavator with a clamshell or orange-peel bucket and to operate it as a dredge or as a revolving crane for handling coal and similar materials. An operator and a helper are needed for its operation.

Wheelbarrow.—A wheelbarrow with wooden handles and steel bowl and wheel is the most popular for general use on construction work. A barrow with wooden handles possesses several advantages over an all-steel barrow although there is practically no difference in weight. Wooden handles possess the advantages that they do not become extremely hot to the touch in warm weather or extremely cold in cold weather. They provide a firm grip and are easily and cheaply replaced when broken.

It is best to employ barrows which can be dumped sideways for handling earth, cinders and for general wheeling purposes. The operation of emptying a side-dumping wheelbarrow is much less fatiguing than emptying an end-dumping barrow. Side-dumping barrows also are made with long handles which allow the barrow to be drawn behind the workman without interfering with his walking. The economic limit for transportation of earth in wheelbarrows is about 200 feet.

Wheelbarrows for concrete work are constructed with deep bowls shaped so that they can be dumped at the front corner of the barrow. They are very useful for general purposes, for transporting wet concrete, mortar, sand, and broken stone. Concrete barrows are made with short handles to give control when handling wet concrete. They should be wheeled in front of the workman both when full and when empty. When a concrete barrow with short handles is drawn behind a man, the cross-braces interfere with his walking.

Contractors' barrows are on the market which are constructed in the same manner as concrete barrows but have slightly longer handles and are well adapted for all-around work.

Horse Carts.—Horse carts are used in construction work where the materials have to be transported a distance that exceeds the haul for which wheelbarrows or scrapers are economical. They possess advantages over the motor truck in economy when they are at rest a good portion of the time due to their being loaded by hand or to other reasons. They are useful when the haul is comparatively short and where the ground hauled over, especially at the dump, is rough and uneven.

The relative economy of horse-drawn carts to auto trucks on long hauls can be judged by bearing in mind the fact that a team is able to travel only about 20 miles in a day over good roads. With a haul of 2½ miles loaded, a team will be able to make only four trips in a day without any allowance being made for loading.

Carts drawn by a double team will prove more economical than single carts, as their capacity, usually about 2 cubic yards for double carts and ⅔ cubic yard for single carts, gives more yardage per horse and as the expense of the driver per cubic yard is more than cut in half. The single cart, however, will be found useful in many cases when the quantity of work is small or where driving space is limited or where the nature of the ground is such that a light single cart can move around to better advantage.

It is usual when carts are to be loaded by hand to require the driver to assist in the loading, though frequently an extra amount in wages is allowed him in such a case. When single carts are used on small jobs, it is economical when the haul is short to have one man do the driving for two carts.

Single carts are constructed to be emptied by dumping from the back end. Carts for double teams may be obtained constructed either to dump from the back end by tilting the body, or to dump through the bottom by means of the hinged parts forming the bottom of the cart. The economical length of haul for single carts is usually assumed to be 600 feet, the same for double carts is about 1000 feet.

A horse-drawn cart or wagon possesses the advantage that it can travel over wet top soil when loaded, without sinking into it. Under similar conditions, a motor truck will usually become mired in the mud.

Motor Trucks.—Automobile trucks are used largely on excavating work in conjunction with power shovels, for deliveries of materials to the work, and for general hauling and transferring of materials and supplies on large operations. Motor trucks of large capacity holding 5 to 6 cubic yards are most suitable for use with power shovels and for transporting materials over long hauls.

For ordinary trucking and transferring of supplies and tools about the site of an industrial plant during construction, nothing is more serviceable than 2-ton trucks. For work that has to be pushed to completion under pressure, they are invaluable, for they can be driven quickly from place to place and deliveries

can be made in a small fraction of the time required by slow-moving and laggardly teams. The dumping models of 2-ton trucks are usually too short to carry lumber in lengths of 16 feet. A stake truck with a flat, stationary body is very adaptable and may be used for transporting lumber, sand, and broken stone, though it has the disadvantage that the matetials have to be unloaded by hand.

Concrete Mixers.—Machine mixing of concrete materials has almost entirely superseded mixing by hand because of its convenience, its economy, and the superior quality of the resultant concrete. A concrete machine is made essentially in two parts: the drum in which the mixing takes place, and the power unit which furnishes the power for turning the drum.

In the majority of machines the drum is simply a revolving steel cylinder partly closed at the ends and with steel paddles or vanes attached to the interior of the rounded sides of the cylinder that aid in the operation of mixing the cement, sand, and broken stone with which the drum has been charged.

The sizes of concrete mixers are rated according to the capacity of the drum, which capacity is stated by the manufacturers in cubic feet of mixed materials, and is always approximately equal to the total cubic feet of stone in the batch. On the work, a mixer is often designated as a one-bag mixer if it is proportioned to take a batch of materials containing one bag of cement or, similarly, a two-, three-, four- or five-bag mixer.

TABLE 1.—RATINGS AND CAPACITIES OF CONCRETE MIXERS

Description	Cubic feet										
Mixed concrete per batch	3	4	5	7	8	10	12	14	21	28	56
Unmixed material per batch	4	5	7	10	10	14	15	21	32	42	80
Hourly output, cubic yards	4½	6	7½	10½	12	14	18	21	30	40	80

The manufacturers of concrete mixers have agreed upon standard sizes and ratings of mixers. The rating of a mixer or its number is based on the quantity of mixed concrete of 1–3–6 proportions, expressed in cubic feet, that a mixer can mix in one batch.

Table 1 gives the ratings of various sizes of concrete mixers with the quantities of unmixed materials contained in a batch and the hourly output at the rate of 40 batches per hour, expressed in cubic yards of mixed concrete.

Mixers may be obtained that are equipped with an elevating charging hopper which does away with the necessity of a charging platform elevated above the ground and the attendant labor of charging the mixer by wheeling the barrows up an incline to the mixer hopper. A charging hopper permits a saving of considerable time and is an economical, worth-while feature.

The motive power of the mixer may be furnished by a gasoline engine, a steam engine, or an electric motor, each class of power having advantages which recommend it for use under certain conditions.

The *gasoline-driven mixer* is light in weight, easily portable, and does not require highly skilled help for its operation; for these reasons, it is convenient and economical to use. It is particularly adapted to mixing concrete for small jobs and for foundations, concrete floors of buildings, and similar work on which the mixer will be used in different locations scattered over large areas and when it is necessary to move the mixer frequently.

The gasoline-driven mixer is seldom used in connection with storage bins for materials, as usually other power, either steam or electricity, is already installed for running bucket conveyors and screens in connection with the bins and the same power is then available for running the mixer. When the gasoline engine attached to a mixer fails to operate, the trouble will usually be confined to the ignition system; but when the engine is attended by a competent mechanic, it will give little trouble.

The *steam-driven mixer* is a very reliable performer and seldom causes any delay in the mixing operations. When large quantities of concrete are to be mixed and electric current is not convenient, the steam mixer is the one to use. This type of mixer can be furnished without a boiler or may be had with boiler and engine complete. The type without a boiler is much used in connection with material storage bins.

One type of portable steam-driven mixer is widely used on concrete road work, and is equipped with boiler, engine, and elevating charging hopper, as well as with an automatic discharging bucket which when loaded travels outward from the machine on a boom extending over the place of deposit. This machine

while expensive is a very efficient producer. The ordinary portable type of steam-driven mixer with engine and boiler is a very heavy machine and is not adapted to work requiring frequent changes of position over uneven ground.

Electrically driven mixers can be obtained in light, portable machines or in the largest sizes of mixers manufactured. It is a very easy machine to operate where electric current is available and is particularly well adapted to work in fixed installations in connection with storage bins. This mixer both in the portable machines and fixed installations is a decidedly satisfactory one to use, provided it is always possible to furnish it with the electric power. The operation of starting and stopping the mixer is accomplished by simply closing or opening an ordinary knife switch.

Hoisting Engines.—In selecting a hoisting engine it is necessary to keep in mind the purposes for which it is to be used, as a different number of hoisting drums, winch heads, and modifications in other parts is required for different classes of work. Engines may be procured with or without boiler attached. All hoisting engines designed to operate by steam can be operated equally well by compressed air.

The hoisting engine with boiler attached, which is so widely used in construction work, scarcely requires a minute description. In general, the best engines are designed with two cylinders, one on each side of the engine. The cranks are set at 90 degrees with each other to prevent the engine from getting caught on dead center and to give a uniform and steady hoisting speed while operating.

The hoisting drums are loose on the shafts and gain their motive power by a friction clutch, which is thrown into gear by a hand lever. When the friction is thrown into gear, it causes the drums to revolve and hoist the load. When the friction is released, any weight on the hoist line will cause the drum, running freely, to revolve in the reverse direction. The standard friction-drum hoisting engine is equipped with a powerful band brake capable of holding any load the engine can hoist. Hoisting engines with single drums intended for special purposes, such as operating elevators, may be obtained which are designed to reverse and to hoist in either direction.

For pile driving and other work where a quick lifting speed is desired, the diameter of the drum may be enlarged on all engines

by wooden lagging bolted to the drum, special provision being made in the drum in the way of pockets and screw holes for this purpose.

Pile driving is the hardest work required of hoisting engines, the boiler being the first to show a lack of power when the work is excessive. The boiler attached to a hoisting engine is a vertical fire-tube boiler, very simple in construction, as shown in Fig. 8, and is operated at a steam pressure of about 100 to 125 pounds. These boilers are made with capacities ranging from 8 to 60 horsepower giving a lead-line pull of 1 to 8 tons.

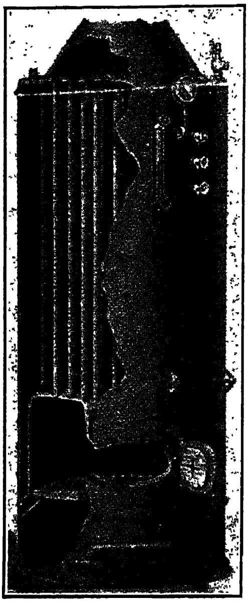


Fig. 8.—Vertical boiler.

A hoisting engine with *one friction drum* may be used for simple hoisting work which requires the use of a single hoisting line as in pile driving, gin-pole work, and for operating the hoisting line of a derrick.

When the single-drum engine is used for pile driving, the drum operates the hammer line and the winch head is used for placing piles in the pile driver leads and for moving the machine. A hoisting engine with two drums, however, is better adapted for general use and is worth the small increase in cost.

For operating material hoists in building work a single-drum engine may be procured, which is equipped with a winch head.

Hoisting engines with two drums are extensively used for general construction work. The two drums allow two main hoisting lines to be used. The winch heads on the outer ends of the drum shafts accommodate two auxiliary lines. When employed for pile driving, the rear drum adjacent to the boiler is used for operating the hammer rope, leaving the front drum available for dragging piles to the machine and hoisting them to place in the pile-driver leads. Special pile-driving engines are made with extra-long drums which will hold a large amount of rope without running onto the second wrap, a feature which does away with excessive wear of the line. The winch heads may be used for moving the machine and for other operations.

When a two-drum hoisting engine is used on derrick work, each drum takes one of the two derrick lines. The boom-operating rope or boom-topping lift is wound upon the rear drum, the load line from the hoisting tackle is wound on the front drum. If it is desired to swing the boom by engine power, a special slewing device should be provided for the purpose and should be placed just in front of the other drums. This swinging gear may be obtained designed to be on the same engine bed with the other drums or on a separate bed casting of its own.

Engines with Three Drums.—The three-drum engine is necessary for use with derricks operating clamshell, orange-peel, or other two-line grab buckets and for all similar cases where a drum is necessary to handle a dumping line. The forward drum is used for raising and lowering the boom and the other two drums for operating the two bucket lines. Either the holding or the closing bucket line may be run to either of the two drums.

Other hoisting powers may be employed on construction work besides the steam hoisting engine. The latter requires the services of skilled engineers for its operation and where a hoisting engine will be used only occasionally, as in certain kinds of derrick work, the presence of skilled operators and the constant use of fuel may prove expensive. In such a case, a gasoline-driven, friction-drum hoist may be used to good advantage. Electrically driven hoists are also procurable to suit every purpose imaginable and like the gasoline engine they do not require highly skilled operators nor use fuel and power except when in actual use.

Portable steam boilers are useful for furnishing steam for operating steam pile hammers, rock drills, pumps, air compressors, and hoisting engines, for heating, and for other purposes. Standard sizes may be had in capacities of 5 to 100 horsepower. Where space is limited, an upright type may be used similar to the boilers commonly furnished with hoisting engines (see Fig. 8). When space is not a consideration, a horizontal, locomotive-type boiler may be selected. Both types of boilers may be obtained either mounted on wheels or on skids as may be desired.

Pumps.—A pump for construction purposes must be able to handle water containing mud and grit without the latter affecting its efficiency or causing serious wear. The most popular types of pumps are the diaphragm trench pump, the centrifugal pump and the pulsometer pump. Such pumps are of simple design and give very little trouble by failure of the pumping mechanism

itself. Over 75 per cent of pump trouble is caused by leaks in the suction at some point.

A diaphragm pump is adaptable to handling moderate quantities of water and is made in two or three sizes. The sizes are designated by numbers, the number agreeing with the diameter of the suction hose expressed in inches. A pump with side suction and a 3-inch suction hose will be found the most satisfactory for all-around use. The single pump is usually operated by hand; double or single pumps may be procured that are equipped with a small gasoline engine to furnish the power. The interior of a diaphragm pump is very accessible and contains two simple flap valves.

Centrifugal Pump.—A centrifugal pump is peculiarly adapted to being driven by electric motor, but it is also designed to be propelled by power from a steam or gasoline engine. It is useful in handling large quantities of water. It is noiseless in operation and does not require constant attention. When handling water containing cement or lime, the impeller in time becomes clogged with a hard, thick coating of lime deposit, which is impossible to remove by chipping. When this occurs, the coating may be easily removed by immersing the impeller in a weak solution of hydrochloric or nitric acid and water.

Pulsometer Pump.—A pulsometer pump is operated entirely by steam. It may be operated in a suspended position and for this reason is useful in work where it is impractical to provide a foundation for a pump, such as sinking shafts, deep sumps, or in other places where, on account of blasting or other reasons, it is necessary to have a pump which is readily removable. The pulsometer may be hung from a projecting beam, tripod, or similar device and arranged with suitable tackle to be raised or lowered at will. It may be lifted and swung out of the way by a derrick or other means and replaced quickly in a similar manner. In its capability of operation while in suspension and of being lowered or raised and swung about without at all interrupting its work, the pulsometer pump is in a class by itself. The pulsometer pump should always be provided with steam hose and flexible steam connections.

The pulsometer pump requires very little care while pumping, as there are no parts to oil. A globe valve should be inserted in the steam pipe close to the pump to regulate the supply of steam required. When steam is admitted to the pump it condenses,

causing a vacuum which fills with water taken up through the suction hose. A ball inside the pump acts as a valve and admits steam in such a manner as to force the water out of the pump into the discharge hose. When steam is first admitted to a pulsometer, the pump will often fail to act. This is due to insufficient condensation. The remedy is to direct a stream of cold water from a hose against the pump or to fill the pump with cold water from the priming hose. This will cause more complete condensation and the pump will start emitting water.

Wood-working Machine.—There are only a few power-driven, wood-working machines which are economical to purchase for use on construction work. The extra handling of lumber necessary to get the material to and from the machines together with their cost usually throws the balance in favor of hand labor.

An efficient machine which is in general use is the electric or air-driven boring machine. This boring machine is light and easily transported and bores holes very quickly. It is a great labor- and time-saving device. Holes bored with it are more likely to run straight and true than holes bored by hand. Where many holes have to be bored in heavy timbers, it proves itself a very economical and convenient machine.

Machine saws are economical when there are large quantities of heavy timbers or heavy planks to be sawed to lengths. They are particularly convenient when large quantities of wooden wedges have to be cut. They are not economical for sawing light boards. Machine saws which may be set up where the timbers are to be used are preferable. Saws which are placed in a permanent position and which are intended for sawing timbers to be used in various scattered structures entail a great deal of handling and carting of lumber which may prove very expensive. A portable gasoline cross-cut and rip saw is procurable which is very useful on dock work.

Pile Drivers.—When piling is required and the necessary length of the piles has been determined, it is necessary to decide upon the type of pile-driving machine and equipment to be employed. The choice between pile-driving machines is restricted to selecting either a drop-hammer pile driver or some contrivance equipped with a steam pile hammer. The location of the piles, whether or not in an accessible position on level ground, and the number and spacing all have an influence in making a proper selection.

Drop-hammer Pile Driver.—The pile-driving machine employing a drop hammer, is too well known to require any description. It is undoubtedly the most efficient and satisfactory device for driving piles. It consists in general of three parts, the drop hammer, the leads in which the drop hammer moves, and the bed which serves as support for both the leads and the hoisting engine.

The drop-hammer machine is very positive and dependable in action and outside of the hoisting engine entails very little operating expense. As the weight of the hammer is always known, the penetration of the pile under the last few blows gives a pretty sure indication of the load the pile will be able to sustain. In hard driving, the drop hammer will usually do faster and heavier work than the steam hammer. The leads should be of sufficient height to take the length of pile to be driven.

PROPORTIONS

Height of Pile-driving Leads, Feet	Weight of Hammer, Pounds
30	1500
40	2000
50	3000
60	4000

Steam Pile Hammer.—A steam hammer derives its driving power from a vertical piston propelled by steam power which moving up and down delivers hammer-like blows on the head of the pile. The weight of the hammer furnishes a suitable resistance to the reaction of the piston and keeps a steady weight on the head of the pile.

The steam hammer may be suspended from the end of a derrick boom or revolving crane or may be operated in the leads of a pile-driving machine. When suspended from the end of a boom, the steam hammer is particularly useful for driving piles in comparatively inaccessible places, as in shallow water near shore, where it would be impractical to use a floating pile-driving machine. It is a very convenient tool for driving piles in the bottom of a trench or in a deep excavation.

The use of a steam pile-driving hammer is particularly advantageous for driving piles in excavations, as the pound occasioned be a steam hammer is much less than that caused by the drop

hammer. There is consequently little tendency to shake the banks down or to loosen timbering and sheet piling. The expense of cribbing necessary for supporting a drop-hammer machine is likewise avoided.

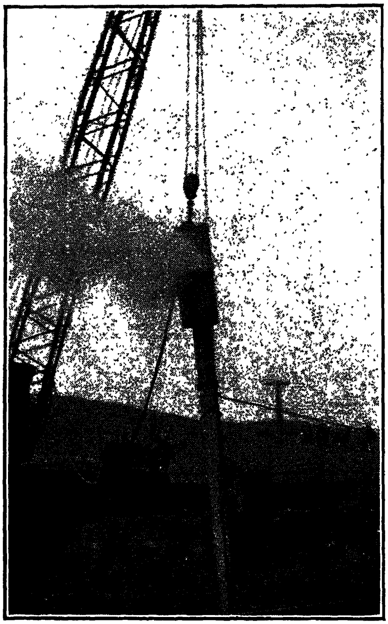


FIG. 9.—Steam hammer hung from crane.

Other advantages of the steam pile hammer are that the cost of loading and unloading pile-driving leads and hoisting engine is saved. Where piles have to be driven in scattered clusters, the use of a steam hammer will often save the time and expense which would be consumed in rolling and turning a heavy drop-hammer machine. This is particularly true if the steam hammer can be suspended from a boom of a revolving crane. The steam hammer, however, uses great quantities of steam and unless a large boiler is provided, it will be necessary to have frequent periods of inaction for the boiler to regain sufficient steam pressure.

Figure 9 shows a steam hammer hung from the end of a revolving crane and used to drive piles in the bottom of an excavation close to railroad tracks. The photograph also shows the manner of supporting the piles in a vertical position when no leads are used.

CONSTRUCTION EQUIPMENT AND SMALL TOOLS

Acetylene torch	Ammeter
Acid	Angle iron
Adze	Anvil
Air compressor	Asphalt tools
Air drill	Auger
Air reamer	Automobile
Air tank	Axe

Bag
Bar bender
Bar, claw
Bar, crow
Bar cutter
Bar, pinch
Bar, wrecking
Barge
Battery
Bell
Belt conveyor
Belting
Bib, hose
Bit, auger
Blacksmith tools
Blade, hacksaw
Blasting machine
Block, chain
Block, tackle
Blower
Board, drafting
Boat
Bob, plumb
Boiler
Blow, torch
Bolt
Bolt cutter
Book, time
Boom, iron
Boots, rubber
Boring machine
Brace
Broom
Brush, paint
Bucket
Buggie, concrete
Burning torch
Buster, concrete
Butt

Cable
Camera
Can, sprinkling
Canthook
Canvas
Car, flat
Car, push
Car replacer
Carpenter tools
Catch, cupboard
Caulking iron
Chain
Chain block
Chain hoist
Chair
Chisel, cold
Chuck
Clamp, air hose
Clamp, cable
Clip, Crosby cable
Cloth, tracing
Cloth, wire
Coat, waterproof
Cock
Compressor
Concrete chute
Concrete mixer
Connection, hose
Conveyor
Copper, soldering
Cord
Corr. iron cutter
Corr. iron rivet set
Coupling, hose
Grab
Crane
Crayon
Crusher, rock
Cutter, bar

Derrick
Desk
Diamond point
Die
Dinkey
Dipper
Divider
Dolly bar
Drawing knife
Drift pin
Drill, electric
Drill
Drill post
Drill, ratchet
Drill, stone
Driver, pile
Dynamite

Emery cloth
Emery wheel
Engine
Exhauster
Eye bolt

Faucet
File
First-aid kit
Forge
Fuller, blacksmith
Furnace, plumber's

Gage, air
Gage, track
Gin pole
Grindstone
Guy clamp
Guy wire

Hack saw
Hammer
Hammer, pile
Hammer, rivet
Hand gage
Hand line
Handle
Hardware
Harness
Hatchet
Heater, tar
Hod
Hoe
Hoist
Hoisting bucket
Hoisting engine
Hook
Hose, air
Hose coupling
Hose, rubber
Hose, steam
Hose, water
Hydrant

Jack, ratchet
Jack, screw
Jack, track
Jinniwink
Journal box
Jute

Kettle, tar

Ladder
Ladle
Lag screw
Lamp
Lantern
Lath
Lead furnace
Lead melting
Lead pot and ladle
Level
Level rod
Lock
Locomotive

Mallet
Marking pot
Mat, blasting
Mattock
Maul
Medicine chest
Metallic tape
Meter
Mixer, concrete
Mop
Motor
Motor boat

Nail
Needle, sail

Oakum
Old man
Oxygen hose
Oil can
Oil stone

Packing, valve
Pad lock
Pail
Paint
Peavy
Pick
Pick-up cart
Pile
Pile hammer

Pin, cotter
Pipe
Pipe cutter
Pipe threader
Plane
Planer
Pliers
Plow
Plumbers furnace
Plumbers, tools, equipment
Post, drill
Post-hole digger
Powder
Pulley
Pump
Punch, backing out
Punch screw
Punch and shears
Putty knife

Rail
Rail splice
Railroad car
Rake
Rammer
Rasp
Ratchet drill
Reamer
Rigger screw
Ripping bar
Rivet tool
Road roller
Roller conveyor
Roofing tools
Rope, Manilla
Rope wire
Rule

Safe
Sand-blast machine
Sand paper
Sand screen
Saw
Saw, cross-cut
Saw, frame, hack
Saw, hand
Saw, power
Scale
Scoop
Scraper, drag
Screen, sand
Screw
Screw driver
Set, rivet
Shackle
Shear
Shear leg
Sheave
Shovel
Side-dump car
Skip car
Skip, derrick
Sledge
Snips, tin
Soap
Solder
Soldering copper
Spade
Square
Steam hammer
Steam shovel
Steel square
Stiff-leg derrick
Stock and die
Stove
Swedge
Swing cut-off saw
Switchboard

Table, saw
Tack
Tank
Tank wagon
Tap, pipe
Tap, bolt
Tape
Tar buckets
Tar dipper
Tar kettle
Tar mops
Tarpaulin
Tent
Thermometer
Threading machine
Tinner's tools
Tongs, blacksmith
Tongs, rail
Tool box

Tool steel
Torch, cutting
Tower, concrete
Tower, hopper
Tractor
Transit
Traveler
Tripod
Trowel
Truck
Tub, mortar
Turn buckle
Turntable
Tuyere iron
Twine

Valve
Vise

Wagon
Washer
Waste
Welding torch
Welding machine
Wheel scraper
Wheelbarrow
Wick, lantern
Wire, annealed iron
Wire insulated
Wire rope
Wrench, chain
Wrench, construction
Wrench, monkey
Wrench, open jaw
Wrench, pipe
Wrench, Stillson

CHAPTER II

EXCAVATION

Lines and Grades.—Before the actual work of excavating for a foundation can be started, the position of the structure must be located by outlining the corners and the other important features with stakes driven into the ground. The exact positions of these points are marked on the tops of the stakes by small nails driven in flush with the tops. Stakes that serve in locating concrete chambers, tanks, or other structures which will be entirely

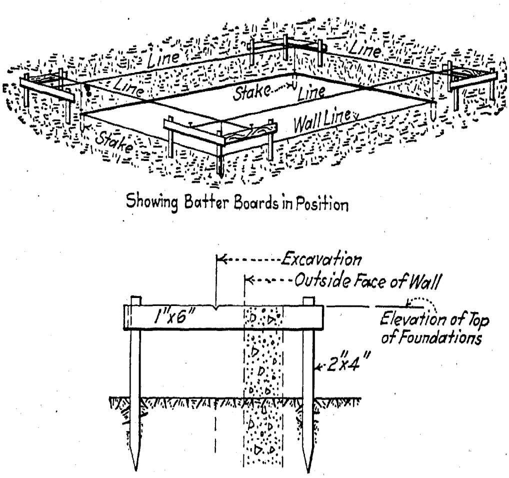


FIG. 10.—Batter board with wall and excavation lines.

underground should mark the intersection of the outside lines of the walls.

Stakes locating outside corners of buildings should be placed at the intersections of the building lines. The building lines are usually assumed as the outside surface of the framing for frame buildings and as the exterior surface of the brick masonry for buildings with brick walls. The positions of all column footings, also, are marked by staking out the column centers. The working

lines for steel mill buildings are fixed on the ground by the stakes locating the column centers.

The height of the top of foundation or the floor line may be marked upon the stakes by the surveyor, but it is better to have the grades fixed by means of batter boards located at the corners of the structure (Fig. 10). After batter boards are erected, the stakes are no longer essential, but may be permitted to remain in position until the work of the excavating dislodges them.

Batter Boards.—Typical batter boards for locating a corner of a structure are shown in Fig. 10. As may be seen in the figure, the batter boards are horizontal 1-inch boards nailed securely to 2-by-4 stakes driven firmly into the ground about 5 feet outside of the edge of the excavation. Nails are driven into the tops of the boards in such positions that lines attached to them will outline the position of the building line, the outside face of the foundation wall, or the neat line for the excavation, as the case may be.

The batter-board posts having been driven into the ground, the boards should be nailed to them with the top edges exactly level and at a known elevation with respect to the floor lines. It is desirable where possible to have the tops of all the batter boards at the same elevation, though a sloping surface to the ground may make this impossible without extending some of the batters to an impractical height. It is customary to fix the elevation of a batter board so that the top of the board will be on a level with the top of the foundation. After the boards have been nailed to the posts at the proper level, the position of the building lines should be marked on the batter boards. These points may be located by the engineers with a transit instrument or by stretching a line from board to board with a plumb bob suspended from it over the nail in each corner stake.

The location of the building lines should be marked first on all batter boards by a nail driven into the top edge of the board and the point further identified by a crow's foot or similar mark. All the other lines, such as the face of foundation wall and the excavation line, may be located on the board by short measurements from the nail.

To distinguish the points from each other, a saw cut or a notch cut with a knife may be used instead of a nail for marking the position of the excavation line. As the foundations will be the first part of a structure to be constructed, a nail projecting about

an inch above the edge of the batter boards and locating the face of the foundation wall is a great convenience in securing the line and, to avoid confusing this nail with the nail marking the building line, the latter may be driven in flush.

After the batters have all been erected and the points have been marked on them, the lines should be stretched from batter board to batter board along the building lines and all dimensions should be checked to see if they agree with those given on the plans. If the structure is rectangular and small enough, the diagonal distances between the intersections of the lines should be measured. If the lines are truly at right angles these distances will be equal.

When it is impractical to measure diagonals in this way, the lines may be tested for being at right angles by employing the ratio of the three sides of a right-angled triangle whose two short sides are 3 and 4 feet and the long side of which is 5 feet in length or any multiple of these lengths. To illustrate: To test two lines for being at right angles, measure 3 feet on one line from the intersection and 4 feet similarly on the other line, the length of the remaining side of the triangle should be 5 feet. The points may be marked precisely on the lines by inserting a pin or piece of fine wire into the cord. As the lengths just given are too short for practical work of any size, distances five times as great may be used or 15, 20, and 25 feet.

The lines having been established and proven true and square, the grades on all batters should be rechecked to make sure that the work is being done at the correct elevation. When this has been done, everything is ready for the excavating.

Lines and Grades for Trenches.—The position of a trench is first marked out upon the ground by stakes driven at intervals along the center line and the trench digging is started with these as a guide. It may be useful in some cases to mark the depth of cut on each stake, but usually it is not necessary. After the digging has progressed to a sufficient depth, heavy planks should be placed on the ground across the trench at intervals and secured against displacement. Should the trench be a wide one, 8-by-8 or similar timbers may be used instead of planks. The center line should be marked on every plank together with the elevation of the top of each plank.

A piece of 2-by-4 scantling or something similar is then nailed vertically to the edge of each plank, as shown in Fig. 11, with one

edge on the center line of the trench. A nail is then driven into that edge of the 2 by 4 which is on the center line. The nail should be located at a convenient fixed distance above the grade of the bottom of the trench. The correct location may be measured down from the top of the plank in each case, a line stretched from nail to nail, and the correct grade obtained from it at any point. After the nails are in place they should be sighted to check their alignment.

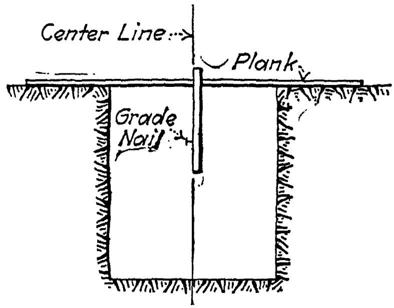


FIG. 11.—Line and grade for trench.

Machine Foundations.—Frequently machine foundations have to be built inside a building for several machines which will be operated in connection with each other. To lay out this class of work accurately, two of the important center lines shown on the plans at right angles to each other are selected and made the chief lines to be located on the batter boards (Fig. 12). By means of

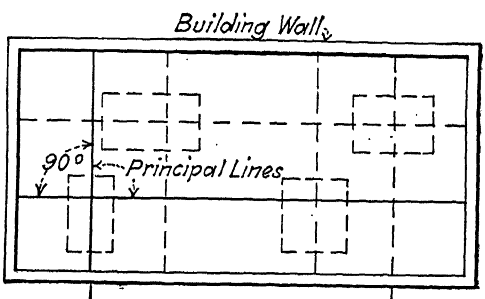


FIG. 12.—Lines for machine foundations.

these the position of all the other lines may be fixed. The position of one of these two principal center lines is determined, the points locating it are marked on the batter boards, and a chalk line is stretched between the points. The other principal center line is then located at right angles to the first line and is marked on the batter boards. A carpenter's steel square may be used for this purpose if it is not convenient to use a transit instrument.

These two lines having been carefully placed, all others may be located from them. The work may be checked by measuring

the entire distance across between the outside lines and the diagonal distances between the intersections of the lines.

Excavation of Basements.—It is often specified that the top soil shall be removed from the area to be occupied by buildings or other structures and that the area stripped shall extend several feet beyond the area to be occupied by the structure. The layer of top soil usually is 6 inches to 2 feet thick and is saved for spreading over areas which will be planted with grass or trees. The soil should be deposited in large piles where it will not interfere with the work of construction or the storage of materials. The top soil is usually removed by drag scrapers drawn by teams.

Preliminary to using the scrapers, the ground must be plowed thoroughly to break the sod and to loosen the earth. After the area has been plowed once, it is not necessary to use the plow again until all the loosened material has been removed. It is customary to use one of the scraper teams for the plough, when needed. A driver is required for each team and one or two men when loading. One man also is needed to overturn the scoops in unloading them. The expense of these extra men is a noticeable charge against the cost of the scraper work, so it is economical to use as many scoops as the length of haul will permit. Scrapers are usually worked in groups of three or four teams.

The remainder of the material in an excavation for a cellar may be removed conveniently with scrapers, if it is not necessary to cart the excavated material from the premises and provided, of course, that the earth is soft enough to be removed with scrapers. It is usually necessary to transport the excavated earth to some distance from the excavation and in such cases the use of carts or automobile trucks is necessary.

Small cellars are frequently excavated by pick and shovel and the earth is thrown into horse-drawn carts and removed. Carts drawn by double teams are used for this work and may be loaded by groups of five to seven men. When the men can get on all sides of a cart, seven men shoveling can be used economically to load each cart without crowding. When only two sides are accessible for loading, five men are all that can be used advantageously.

As the excavation progresses deeper, a slope or ramp is prepared, preferably to one side of the excavation, to provide for the passage of teams in and out of the hole (Fig. 13). The slope should start well outside the limits of the excavation. The usual

basement excavation will be from 5 to 8 feet deep and as the digging reaches deeper levels, a snatch team or some other means must often be provided to assist the teams in pulling out of the hole.

The method of excavating just outlined may be used for excavating cellars for buildings of all sizes, but where the excavation covers sufficient area to admit a small steam shovel of the revolving type, it will be found much more economical and convenient to use it, than to adhere to the use of the pick and shovel.

The steam shovel in digging its way into an excavation proceeds downward at a slight grade, forming a slope similar to

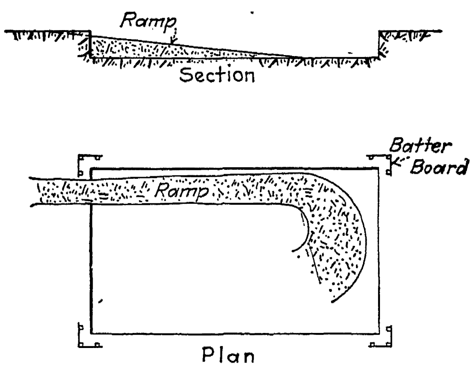


FIG. 13.—Ramp for hauling out of excavation.

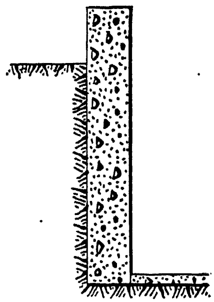
the one mentioned previously. The ordinary steam shovel of the revolving type can dump at an extreme height of 13 feet above the bottom of its traction and can dump into carts standing on the original surface when the shovel is working in a cut which is about 8 feet deep. This means, of course, that the first 8 feet of depth may be excavated and loaded into carts standing on the original surface of the ground and also that if the excavation is to be carried to greater depths, the carts will have to be brought into the excavation to be loaded.

There is a great advantage in loading the carts on the surface of the ground over loading them in the hole, because in the former case larger loads may be handled and far less time is consumed in maneuvering the trucks into position to be loaded.

Carts may be used to transport the excavated earth where the haul is only several hundred feet, but where the earth has to be hauled a long distance automobile trucks should be used.

A steam shovel will load a cart or truck very quickly. Usually three or four dipperfuls from the shovel will make a load. As a shovel will average about two swings a minute when working in good digging, the entire time of loading will take only 2 or 3 minutes. It will be readily seen that the rate of progress is controlled more by the number and handling of the trucks than by any possible manipulation of the steam shovel.

After a shovel has finished its excavating and has worked itself up the incline and out of the hole, the portion of the slope which remains will have to be excavated by hand and thrown into



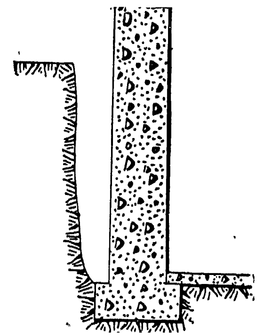


FIG. 14.—Wall built against the bank. FIG. 15.—Wall with projecting footing.

carts. When the excavation is a deep one, the yardage in this slope may be considerable and it is frequently dug out by the steam shovel and is replaced by a plank runway supported by suitable heavy trestle bents over which the shovel may leave the hole.

Limits of Excavation.—Concrete foundation walls for buildings with cellars are usually either of plain, rectangular cross-section, as shown in Fig. 14, or designed with projecting footing, as shown in Fig. 15. It is necessary as soon as the digging is started to decide upon the lines to which the excavation will be carried. Where the walls are to be of plain cross-section (Fig. 14), it is possible in firm clayey soils to save concrete form work by concreting against the bank. When it seems desirable to attempt this saving in form work, the bank should be trimmed to the line of the outside surface of the wall.

A majority of constructors, however, do not attempt this saving unless the bank is particularly cohesive; they maintain that the bank has to be carefully trimmed to line, that extra

concrete will be required in any place where the bank crumbles, and that usually forms will be required above ground, anyway, on the bank side. Another disadvantage is that the concrete forms cannot be wired together. The pressure of the wet concrete against the forms must be resisted by braces.

Where the earth has a pronounced tendency to crumble and to cave, the cost of the extra concrete used in filling the voids in the bank beyond the wall line will be greater than the cost of the forms. It will always be found desirable to use forms for both sides of the wall. A bank in this case, should be trimmed to a neat line established at least 4 inches beyond any woodwork of the forms so that the forms may be removed after concreting.

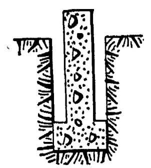


FIG. 16.—For stable soil.

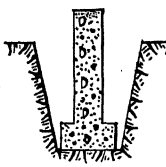


FIG. 17.—For unstable soils.

When the excavating is done by a steam shovel, it is impossible to work close to line in digging.

Excavation for Foundation Walls.—The simplest type of excavation for foundations is that required for buildings designed without any cellar. A trench is dug to such a depth that the bottom of the foundation will reach a subgrade firm enough to support the load which will come upon it, as well as to extend below the frost line. In the states of New York and Massachusetts this latter requirement means a depth of about 4 feet.

In firm soil, the trench should be dug with vertical sides and as wide as the footing (see Fig. 16). Where the soil is of an unstable nature, it is well to prevent caving at the start by trimming the sides of the trench to at least a 1-on-6 slope; this gives a minimum of 8 inches increase in width on each side for the top of an ordinary trench (see Fig. 17). A greater slope than this is often necessary in unstable soils.

Excavation of Trenches.—The excavation of trenches for pipes and sewers is generally done with pick and shovel, although trenching machines or steam shovels may be employed for digging long stretches of trenches where the ground is self-supporting and does not require close sheeting.

In digging a trench in which pipes are to be laid, economy may be practiced by making the trench no wider than is necessary for the size of the pipe to be laid. In a general way, it may be stated that 16 inches is about as narrow as a shallow trench can be dug by a man standing on the bottom of the trench and when a trench is excavated to a depth of over 5 feet, it will have to be given a width of at least 24 inches. For ordinary trench work, the following widths of trenches will be found suitable for the various sizes of pipes where no sheeting is necessary:

TRENCH WIDTHS

Pipe Diameter, Inches	Trench Width, Inches
4	20
8	24
12	30
15	36
24	44
30	50

These widths give 8 to 10 inches outside of the pipe on each side, which is necessary for working space and room for the feet of workmen when straddling the pipe and making the joints.

A trench may be dug with vertical sides in stiff clay or in firm earth, but in most unstable ground the sides will have to be given a batter sufficient to counteract the tendency to crumble or to cave or some kind of plank sheeting will be needed to support the banks. Ordinarily, a slope of 1 on 6 will be sufficient in firm earth if the trench is not allowed to stand open too long.

The amount of batter necessary will depend largely on the character of the ground. Trenches may be dug in wet or silty soil, without resorting to the use of sheet piling, by giving the banks a wide slope of approximately 45 degrees. While this entails additional excavation it will be less expensive than sheet piling in some cases.

When digging a trench, the excavated material should be cast well back from the edge of the trench so as to keep the weight of this loose earth back where it will have little tendency to cause the banks to cave. Round-pointed shovels should be used for digging, shovels with long handles being popular for this work. Large stones and boulders met with in the course of the digging

may be broken with sledges or by blasting with powder. The broken fragments may then be thrown out of the trench. If boulders are encountered which are too hard to break up conveniently and blasting them is not desirable, they may be removed by rolling them into holes dug expressly in the sides of the trench to receive them.

Backfilling.—If it is desired to backfill a trench solidly, the earth should be deposited in layers of 4 to 6 inches and rammed with iron rammers or it may be compacted by flooding thoroughly with a stream of water from a hose. The latter method is particularly effective with sandy earths. Special care should be taken to have all backfill solidly compacted where the trenches pass below roadways or are in the neighborhood of important structures.

Sheet Piling of Trenches.—The supporting of trench banks against caving or other movement may be accomplished by various systems of sheeting and bracing. The method most extensively employed, as well as the most adaptable to changing conditions, is a sheeting formed of vertical sheet piles driven behind continuous horizontal lines of rangers, which are braced at intervals by timbers extending across the trench from ranger to ranger.

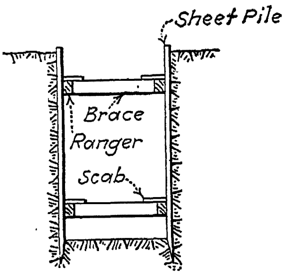


FIG. 18.—Cross-section of sheet-piled trench.

The usual method of sheet piling a trench with close vertical sheet piling is indicated in Figs. 18 and 19. When the trench is dug in comparatively dry earth where there is no tendency for it to run or flow, the sheet piling may be made of square-edged planks. Where the excavation is to be carried through mud or very wet soil the sheeting will have to be installed with close joints and these may be best obtained by using tongue-and-groove or splined planks.

The sheet piling for ordinary trench work is formed of 2-inch planks with 4-by-6 rangers and braces. It is customary for uniformity to use the same size timbers for both rangers and braces, although they may be made of different sizes where conditions seem to call for it.

Piling.—Sheet piling 2 inches thick is commonly used for sheeting all ordinary trench work. Wide planks are expensive

and hard to drive. For these reasons sheet piles of 2-by-6 or 2-by-8 planks are generally used; the 2 by 6 is the cheaper size but the 2-by-8 planks cover more surface and allow the sheeting to proceed at a quicker rate.

The thickness of sheeting planks required is influenced by the intensity of the load brought upon them by the depth of the trench below the surface of the ground and by the spacing of the rangers. Each plank should be considered as a vertical beam spanning between the rangers.

If the usual distance between rangers is increased or surrounding conditions seem to indicate that heavier sheeting is necessary 3-inch planks should be used, but they are very hard to drive by

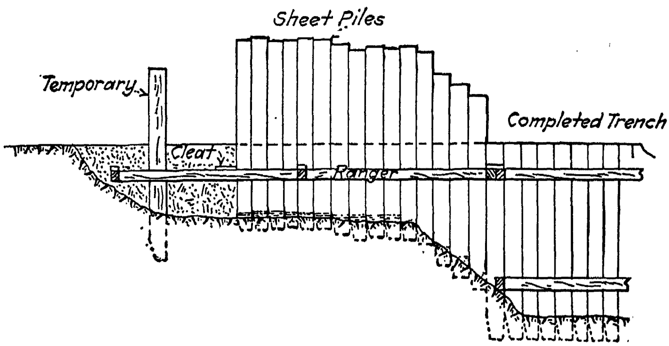


FIG. 19.—Longitudinal section of sheet-piled trench.

hand even in very soft ground. On account of this difficulty in driving, it is best to use 3-by-6 planks which have been surfaced smooth. When 3-by-8 sheet piles are used, a steam hammer or similar device will be required to drive them. There is a small jack hammer that is manufactured for sheet-piling work which is efficient and convenient to use. It may be run by steam power or compressed air and is held to the top of the sheet piles by the man operating it. In dry soil, sheet piles of any size may be installed by digging the point of the pile free, this is known as "digging the piles in."

Rangers.—The rangers may be made of 4-by-6 timbers in trenches dug to a depth of about 7 feet. Trenches carried to greater depths will require heavier rangers, 6-by-8 timbers being suitable to a depth of 10 feet. Over this depth, 8-by-8 and larger rangers become necessary.

The duty of a ranger is to act as a beam spanning from brace to brace.

Considerable latitude is possible in selecting the size of timbers used at various depths in trench work, as the character of the ground plays an important part in determining the load that will come on them.

Rangers are generally spaced 4 to 6 feet apart vertically and usually with the wide side against the sheet piling, as they remain more firmly in place between the sheeting and the braces in that position. Theoretically, however, they would have more strength if turned the other way.

Braces.—The braces should be spaced about 8 feet apart along the rangers to give ample space between them for men to shovel and to throw out excavated material. With rangers 16 feet long, this spacing will bring one brace at the middle of each ranger and one brace at each end, bringing in this way, two braces together where the rangers butt.

The width and depth of the trench influence the size of timbers required for the braces, as the braces must be stout enough to avoid any tendency to buckle when under pressure. The braces should be placed with the long sides vertical unless they are of square cross-section. They should be equipped with a short piece of plank nailed to each end, as shown in Fig. 18, to prevent them from dropping out of place in case they should become loosened in any way. The table below gives sizes of braces which will be found suitable for different widths of trenches down to a depth of 8 feet.

Size of Braces

Width of Trench, Feet	Size of Brace, Inches
4	4 by 6
8	6 by 6
12	8 by 8

Installing Sheet Piling.—When a trench has been dug to the depth at which the banks will need to be supported by sheet piling, the topmost rangers are placed in position and the sheet piles are inserted for driving. The top rangers should be located 2 or 3 feet below the surface of the ground and should be supported by two or three sheet piles driven temporarily on the proper line. The rangers may be tacked or cleated to these piles

until the cross-braces have been installed and permanent piles have been driven.

Sheet piles should be sharpened at the bottom ends in order to decrease the labor of driving them and to insure tight sheeting and full width of trench. The planks should be sharpened at the bottom ends by beveling one side and one edge, as shown in Figs. 18 and 19. The beveled edge will cause the pile when being driven to wedge hard against the pile next to it and to make a close joint.

If the edges of the sheet piles are not beveled, adjacent edges will not keep in contact during driving and small pebbles or stones will work their way between the piles, causing them to separate and to incline from their vertical position. In this manner, spaces of 2 or 3 inches may be formed between piles. These spaces will give trouble as the digging progresses, permitting earth and stones to run through them into the trench. This condition will lead eventually to the formation of voids and caves in the banks, which may lead to dangerous conditions.

To drive sheet piling successfully the piles must be turned so that the side which has been beveled will face toward the inside of the trench. When driving the piles turned in this manner, they will drive outward at the bottom slightly and will insure the full width of trench necessary for placing the lower rangers. If the piles are driven with the bevel turned the opposite way, the piling will drive inward at the bottom and tend to spread outward at the top and to pull away from the top rangers, as indicated in Fig. 20. After the rangers and braces have been installed in the correct positions, the sheet piles with their ends properly prepared by beveling on one side and one edge are placed in position behind the rangers.

In placing the piles behind the rangers for driving, care should be taken to set them exactly vertical. The piles should never be placed and driven one at a time, but a number of them should be placed at one time and held together tightly in a vertical position by cleats nailed to the tops of the rangers, as shown in Fig. 19. The sheet piles on both sides of the trench having been placed ready for driving, each pile in turn should be driven down until the point of the pile is 1 or 2 feet below the bottom of the excavation. If the cleats are used and the planks are sharpened, as shown in Figs. 18 and 19, no trouble should be experienced in driving the piles with close joints.

After the sheeting has been driven as far as it will go with easy driving, the excavation is resumed and as the digging progresses, the piles are driven further downward. In soft ground care should be taken to keep the points of the sheeting buried 1 or 2 feet below the bottom of the excavation at all times. When driving in sand or gravel, it is sufficient to keep the point of the pile merely buried. This alternate driving of piles and digging continues until the position of the next lower ranger is reached. This ranger and its braces are then placed, securing the ranger temporarily in position to one or two piles which have driven true to line. If a pile has worked outward during the driving so that there is a space between it and the new ranger, the bottom of it may be brought back into line against the ranger by digging the point of the pile free, so that the pressure of the earth will force it back to its proper position.

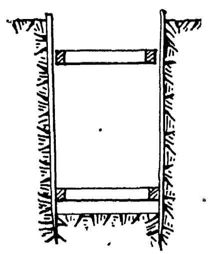


Fig. 20.—Sheet piling driven with bevel turned incorrectly.

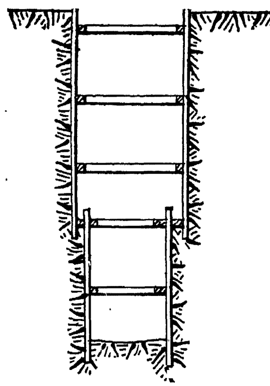


Fig. 21.—Two sections of sheet piling.

A hickory maul will be found superior to an iron sledge for driving sheet piles, as an iron sledge having a small striking surface will split the tops of the plans. If long sheet piles are used, they will project at the start above the surface of the ground well out of reach of men standing on the ground and it will be necessary to start driving them from planks supported on high wooden horses or similar supports.

Lumberyards ordinarily carry planks in stock lengths in even feet up to 16 feet, which makes this depth about the limit to which the excavation should be carried with simple sheeting. At this depth also, the driving of sheeting 16 feet long becomes very difficult. If it is necessary to excavate a trench to a greater depth, a second and lower section of sheet piling may be driven inside the top section, as shown in Fig. 21.

Other Systems of Sheeting Trenches.—Close sheeting is not necessary where a trench is dug in dry, compact earth which has no tendency to run or flow and the excavation needs only to be protected against caving in large masses. With such conditions simpler and cheaper methods of supporting the banks may be used.

Skeleton Sheeting.—Skeleton sheeting is similar to close sheeting in the manner of placing rangers and braces. It differs from

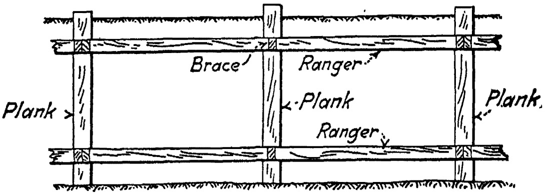


Fig. 22.—Skeleton sheeting.

the latter in that the greater part of the sheeting is omitted. The banks are supported by one or two vertical planks inserted opposite the braces (Fig. 22). Where a section of trench requires closer sheeting, more planks can be inserted. Should regular close sheeting become necessary at any point, the change from

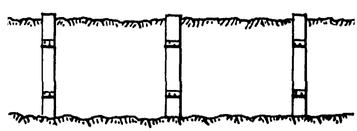


Fig. 23.—Horizontal stay bracing. Fig. 24.—Vertical stay bracing.

skeleton to close sheeting may be conveniently made without any change in timbering.

Stay Bracing.—Stay bracing is the simplest type of bracing for supporting the sides of a trench. It is useful only to prevent the banks of the trench from caving in large masses. No rangers are used and heavy timbers are not necessary as the braces may be made of the same lumber as the planks that are placed against the sides of the trench.

Horizontal stay bracing is shown in Fig. 23, and vertical stay bracing in Fig. 24. The planks may be used in full random lengths in the horizontal bracing and cutting is not necessary. Short planks may be used for the vertical bracing or planks may be cut to the proper lengths.

Horizontal Sheeting.—In this system of bracing the trench may be dug 4 or 5 feet deep and horizontal planks may be laid against the sides of the trench and braced at intervals, as shown in Fig. 25. This is a good system for temporary sheeting in dry earth, as it is not necessary to cut any planks into short lengths.

Bracing Sides of Wide Excavations.—When an excavation must be carried close to an important structure, a street, or the

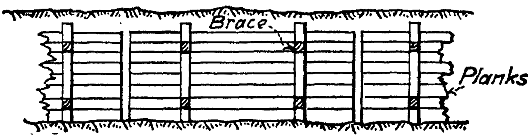


FIG. 25.—Horizontal sheeting.

like, which prohibits the presence of a near-by excavation with unsupported banks, it becomes necessary to arrange for an adequate and suitable system of sheeting and bracing. Where the excavation is relatively wide, the system of sheet piling and timbering, shown in Fig. 26, may be resorted to.

The braces and rangers shown may be 8-, 10-, or 12-inch sticks according to the strain which may be thrown upon them. The

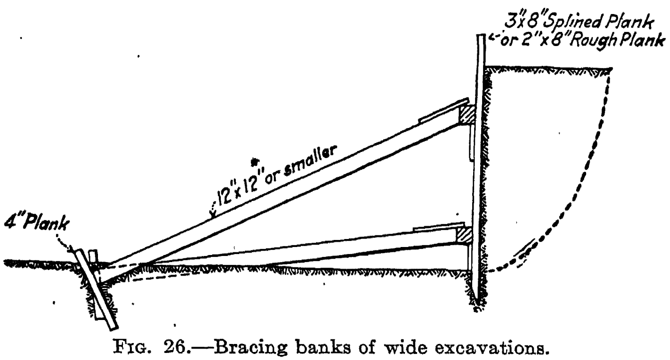


FIG. 26.—Bracing banks of wide excavations.

bottoms of the braces butt squarely against heavy planks set obliquely in the ground.

The braces, as seen in the figure, are placed side by side and butt against separate planks at the bottom. Single planks will provide sufficient bearing where the ground is hard. Where greater spread is desired, so as to give greater bearing on yielding soil, a horizontal short piece of timber may be inserted between

the foot of the brace and the bearing planks, several planks being used in place of the single plank indicated in Fig. 26.

If possible, the sets of braces should be spaced about 10 feet apart. A brace should be located at each joint between ranger timbers. To reinforce the joint and provide a solid bearing for the brace, a corbel block consisting of a piece of thick plank should be spiked fast to the side of the ranger directly across the joint.

A plank scab is nailed on the upper ends of the braces to prevent them from sliding downward on the rangers. The braces are brought to a firm bearing against the rangers by cutting the ends of the braces to a proper bevel or by inserting a wedge-shaped block between them.

Two lines of rangers are shown in Fig. 26. Where the depth of the excavation is not too great, one line of rangers will often provide sufficient bracing. When only one line of rangers need be installed, it should be located at a distance below the surface of the ground equal to one-third of the depth of the excavation. This point is a critical one for two reasons. It divides each sheet pile into two parts of about equal strength. One of these acts as a cantilever beam in resisting the earth pressure. The other part may be regarded as acting as a simple beam supported at each end, although both parts together form a continuous beam.

With the two spans proportioned in this way, the theoretical bending moments are made about equal. The location may be further regarded as a critical one because, according to one theory concerning earth pressures, the center of intensity of pressure of a dry-earth bank in the act of caving occurs at this point. The manner in which a dry-earth bank may usually be expected to cave is indicated by the dotted line in Fig. 26. When more than one line of rangers is to be installed, the selection of the location of each line should be influenced by the principles just cited.

The braces should not be placed at too steep an angle. The top brace, if possible, should be installed at an angle of about 30 degrees with the horizontal. An angle of 45 degrees is a trifle too steep, because at this slope a tendency to lift up is likely to be developed. The lower braces, of course, if there are any, should be given a flatter slope.

The sheet piles may be 2- or 3-inch planks, usually the latter, and they are preferably surfaced and may have either tongued-

and-grooved or splined joints. The splines are nailed in the grooves in the edges of the planks before they are driven. The nails should extend through the spline and go well into the wood beyond it. Two-inch planks will require rangers to be spaced about 6 or 7 feet apart. The use of 3-inch planks will permit the rangers to be spaced 8 or 9 feet apart. The heavier sheeting reduces the number of lines of rangers necessary. Heavier rangers in turn permit greater working spaces to exist between the braces. The 3-inch planks, however, will require the use of a steam hammer or some other mechanical device for driving them, unless the nature of the ground is such as will permit exposure of the pile points by digging the earth away during the driving.

In shoring the banks of an excavation having a depth of approximately 10 feet, there are a few general principles that can be followed that will standardize the design of the shoring. It will be found advantageous not to use timbers for braces less than 8 by 8 inches in cross-section. A timber measuring 6 by 6 is light in weight and can be easily displaced by a moderate force or blow. It is always desirable to use two lines of rangers. In driving sheet piles in the side of a bank there is a strong tendency for the bottom of the sheet piles to work forward unless a second line of rangers is installed, at least temporarily, to hold them in place. When the bottoms of the piles work forward, the upper portion of the piles will pull away from a single ranger. With heavy braces and two sets of rangers in place there is small chance of a cave-in should any timber become displaced.

The work of timbering is started by placing the rangers. Where two lines of rangers are to be used and where the banks of the excavation will stand unsupported long enough, it will be found most convenient to dig down into the face of the bank so that the timbers in the second line of rangers can be placed first. The top ranger timbers can then be supported from them by spacer pieces cut in between the two sets of rangers. Where conditions will not permit adherence to the foregoing procedure, the work of timbering may be started by cutting a shelf in the bank on which the top ranger can be placed or by digging two or three recesses in the side of the bank and inserting in them short posts upon which the ranger can be placed. Care should be taken to set all rangers strictly horizontal and to arrange them parallel to the general lines of the excavation so that the appearance of the work is orderly.

The sheet piles should be sharpened with a beveled point and set in place behind the rangers. The first sheet pile placed should be set plumb and held there by tacking it in place with nails or by cleats. The braces are cut and installed at right angles to the rangers and the work of sheet piling proceeds in a manner similar to sheet piling a trench. When the sheet piling is driven to the final depth, cleats should be spiked to them

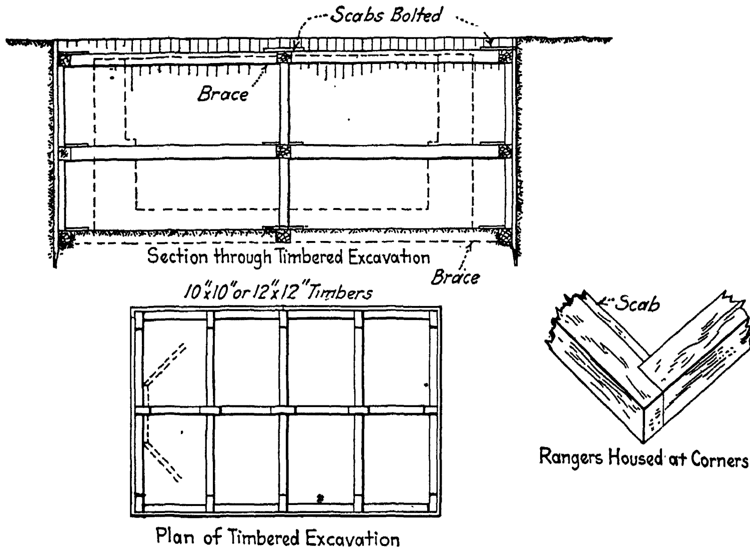


Fig. 27.—Timbered excavation.

under each ranger to act as a support should a timber be accidentally loosened.

Deep Excavation in Soft Ground.—The operation of excavating for structures to be built below the surface of the ground has often to be accomplished in soft and unstable soil. Such excavations ordinarily do not cover extensive areas but are usually confined to holes measuring 30 to 40 feet in width. Excavations of this kind may be started by shoveling the earth into wheelbarrows for removal until the digging has reached a depth where the use of wheelbarrows is no longer practical or where the digging has entered material of such a nature that it becomes necessary to support the sides of the excavation.

When the sides of the excavation have been protected by sheeting and bracing, the remaining material may be taken out by

handling the excavated material from platforms erected on the braces. On larger work the earth may be shoveled into a bucket and removed by a stiff-leg derrick located on the edge of the excavation. A grab bucket operated by means of a derrick will do the work of many men and cut down the cost of excavating.

The sides of excavations of this kind require sheet piles and timber supports similar, in a general way, to those used in sheet piling a trench, but the timbering should be of heavier and more permanent construction. The sheeting of a trench will usually remain in place but a few days whereas the timbering for an excavation for this class of work may remain in place for several months.

A simple case of excavation in soft ground for a structure to be built below the surface is shown in Fig. 27. Usually one of the dimensions of the excavation is small enough to permit the banks to be braced by single timbers placed crosswise of the excavation and extending across from ranger to ranger. Heavy timbers should be used for the rangers and braces. The braces should be spaced 8 to 12 feet apart to give working space for shoveling and admission of skips. The bottom set of timbers is needed only in soft ground.

The position of the sheet piling should be arranged so as to give a space of 3 feet between the outside of the structure and the piling, in order to provide room for a sump and suction hose for pumping water and to give access for workmen when building the concrete forms. This space also keeps any infiltration of water away from the concrete and provides space in which the water may be collected into drains.

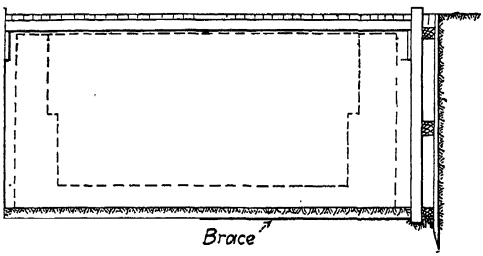
The rangers may be joined together at the corners or may be treated as shown in the chapter on steel sheet piling.

Spreaders or "spacer" timbers are placed vertically between the rangers at the braces, as shown in Fig. 27, to assist in holding the timbers securely in position.

In building a concrete structure, as indicated by dotted lines in Fig. 27, the studs for the concrete forms may be erected and may be boarded up to the underside of the intermediate set of braces. The forms may then be filled with concrete up to this height. The intermediate rangers can then be braced against this concrete and the intermediate cross-braces may be removed. The form studs can then be boarded up to the underside of the next higher set of braces and the forms can be filled with concrete

as before. The process can be repeated in this manner with each set of braces until the walls have been completed.

When a concrete structure is constructed in very wet ground and it is desired that the concrete should be as waterproof as possible, the structure should be built solidly in one piece without any seams or joints along which water might find a passage through the walls. To build a monolithic concrete structure like this, it is necessary to avoid the joints which are formed between each day's work. This may be done by concreting



Excavation Retimbered for Monolithic Concrete Construction

FIG. 28.—Retimbered excavation.

continuously from the time the first concrete is placed until the concrete forms are completely filled.

The arrangement of braces, shown in Fig. 27, interferes with the operation of placing concrete continuously as the braces extend through the concrete forms and must either be boxed in by forms or removed entirely. The procedure commonly adopted to avoid the presence of braces penetrating the concrete is indicated in Fig. 28.

When a monolithic structure is desired, the excavation can be carried down to the final depth with the timbers arranged in the usual manner, as shown in Fig. 27. The system of bracing, shown in Fig. 28, is then installed and the former cross-braces are removed.

The original cross-braces put in when excavating should be so located in plan that the timbers in the final arrangement may be spaced advantageously. The system of timbering employed in the final arrangement is such that the rangers (Fig. 28) are engaged by vertical timbers braced in pairs, top and bottom, by two cross-braces, thus doing away with all intermediate braces running through the concrete forms. The top brace should be located so as to come just above the top of the concrete. The

bottom brace should be located so that it will be just below the concrete, as shown in Fig. 28. The bottom braces, in this case, will have to remain in the ground. The bottom rangers can usually be salvaged, but are more often permitted to remain in the ground with the braces.

Supporting Cofferdam Bracing.—Where the width of a cofferdam is greater than can be spanned by a single timber, each cross-brace can be formed of two or more timbers placed end to end. The joint between them can be spliced on the sides by plank scabs bolted through the braces. In some cases the scabs will be strong enough to support the timbers and any light loading that may come upon them. If the excavating is done with

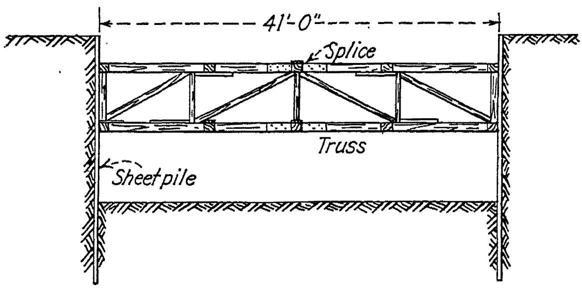


FIG. 29.—Braces trussed.

a grab bucket, the timbering will have to be built heavy enough to take the jars occurring when the bucket comes in contact with them. The cross-braces in the top ring of timbers will usually have to act as a working floor for men and may have to support concrete runways, pipes, and various other articles of equipment. The braces will have to be supported in a substantial way if they are to carry this loading.

The braces can be supported by posts set on the bottom of the excavation, where the subgrade is firm and where the presence of the posts will not interfere with the quality or progress of the work. Where the subgrade is soft or where the presence of posts is undesirable, the timbering may be supported by a trussed structure framed in each set of cross-braces. The trussing may be accomplished either by a system of inclined braces as shown in Fig. 29 or by hog-rods and struts as in Fig. 32.

Trussing.—Figures 29 and 31 show an efficient way of supporting cofferdam timbers by trussing the braces. It will be seen

that the braces are spliced at the center of the span. The splice is supported by a post cut in between the top and bottom timbers. A system of inclined braces runs from the center toward each

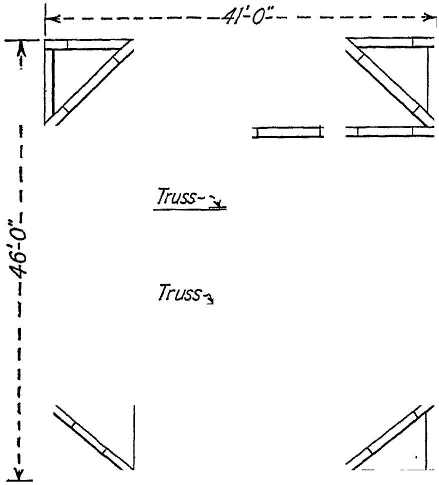


Fig. 30.—Plan of cofferdam bracing.

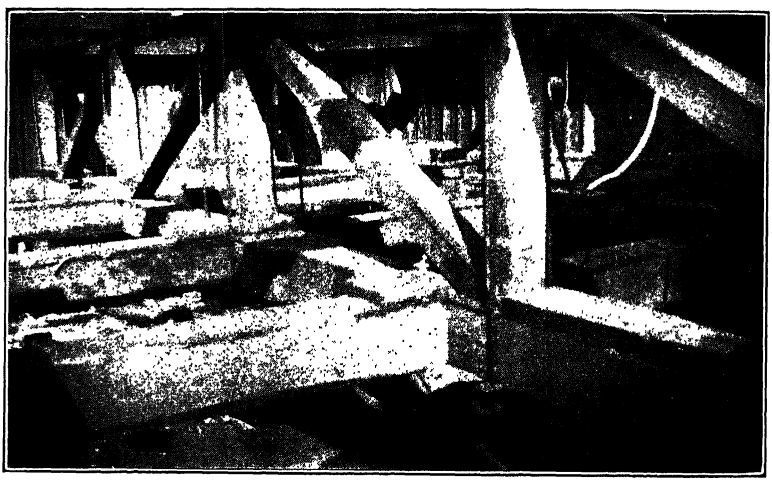


Fig. 31.—Trussing.

end of the truss. A pair of ⅞-inch rods at each vertical post tie the top and bottom timbers together. The inclined braces are framed neatly against the sides of the post and horizontal timbers. A short piece of plank is bolted to the top and bottom

braces and arranged to bear against the post and to take the push of the inclined brace. Each end of the truss is supported by a pair of ⅞-inch rods similar to those at the posts.

A plan illustrating an arrangement used to support cofferdam timbering by means of trussed braces is shown in Fig. 30. Note

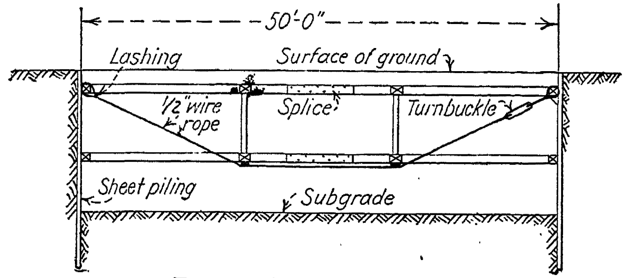


Fig. 32.—Braces hog-rodded.

that the timbering is so designed that only two trusses are constructed. The remainder of the timbering is supported by these two trusses and by the sheet piling of the cofferdam.

Hog-rodding.—Figures 32 and 33 show the bracing in a cofferdam supported by hog-rods formed of wire rope. Here, the

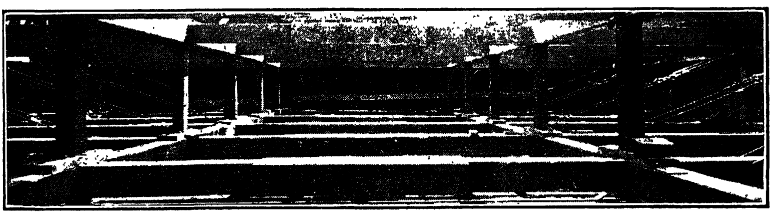


Fig. 33.—Hog-rodding.

cross braces are spliced in the center and scabbed by planks bolted through them. The hog-rodding is formed of ½-inch wire rope. Two cables are used on each truss. A turnbuckle connects each cable with a lashing of wire rope placed around the upper ranger timbers. The turnbuckle is needed to tighten the wire rope. The pressure of the cable on the bottom timber is taken on a steel plate bent as in Fig. 34 to hold the cables in place. A plan of a cofferdam bracing that is supported with wire rope is shown in Fig. 35.

Sheet Piling Small Holes.—In digging small holes 10 to 20 feet square in plan, it will be found a good plan to place all the

sheet piling around the rangers before driving any of them. This will insure an orderly appearing job of sheet piling with tight joints and vertical piles. Before starting the work of driving, several of the sheet piles may be removed, preferably at a corner, to furnish access to the excavation, the piles on either side of the opening being held in a vertical position by cleats nailed to the rangers. The piles should be beveled at the lower ends, as described for sheet piling a trench, if the bottoms of the piles

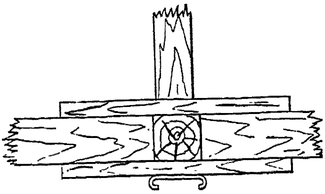


FIG. 34.—Steel bearing plate.

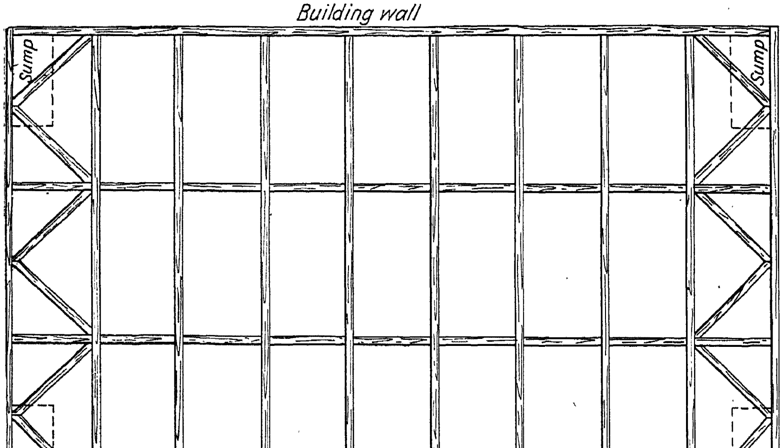


FIG. 35.—Plan of cofferdam bracing.

are to be followed closely by the digging. If the piles are to be driven deep in advance of the excavation, the piles should be beveled equally on both sides, otherwise the one-sided bevel will cause them to work too far out at the bottom.

STEEL SHEET PILING

When Used.—Steel sheet piles should be used to carry an excavation down through ground containing water in large quantity. The main objects to be attained from their use are the prevention of water from entering into the excavation

and the retention of the earth outside the limits of the excavation, undisturbed, and in its original position. In steel sheet piling, also, is found the strength necessary to resist the large pressures usually encountered in excavating in water-bearing soils, particularly, close to the shore lines of large bodies of water. The hardness of the steel is a valuable asset where the piling has to be driven through coarse sand and gravel.

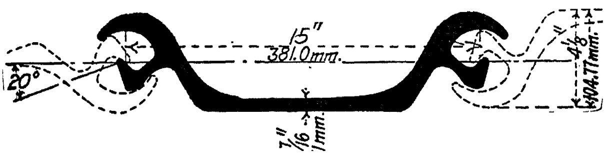


FIG. 36.—Arched-web section.

Steel sheet piling is the only piling which can be depended upon to prevent the passage of water through it. The results obtained by the use of wooden sheet piling are usually unsatisfactory where water is present in abundance. It is extremely difficult to secure tight joints with wooden piling. The impossibility of making unyielding contact between piles aided by the

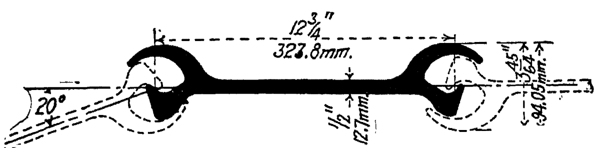


FIG. 37.—Straight-web section.

softening effect of water on the wood will usually permit seepage along the joints between wood piles. An appreciable decrease in strength occurs also when the wood becomes water soaked.

The greater strength of steel sheet piling permits a more economical and less-complicated system of timber supports and bracing to be installed than would be the case were wooden piling to be employed. Other commendable features are that the steel piles may be procured in long lengths and can be driven more easily to the depth required in sheeting deep excavations.

Shapes and Sizes.—Steel sheet piling is made with arched web, as in Fig. 36, or with straight web, as in Fig. 37. A wall of piling of the arched-web type offers greater resistance to bending under exterior pressures than a wall of piling of the straight-web section. The arched web, therefore, permits greater distance

between timber supports. In placing piles of the arched-web section in position preliminary to driving them, the piles should be turned so that the arches reverse with each pile.

The straight-web style of pile is for general use and possesses sufficient strength for piling all excavations except where exceptional strength is required.

Standard rolled-corner shapes are shown in Fig. 38. As will be seen, reversing one of these piles will not change the positions of the two joint flanges. A corner pile of either shape, therefore, may be required, according to the way in which the piles adjacent to the corner are turned.

How They Function.—Steel sheet piling is shaped in such a way that a direct and continuous metal contact is obtained in two lines along the joints. The shape of the joints is such that the heavy earth and water pressures acting on the outside of the pile press it inward, bringing the metal of one pile to bear on the metal of the adjacent pile and, in this manner, make contact certain along the joint. Ordinarily, this contact will provide a waterproof joint and no leakage will occur along the joints unless the piling becomes bent through being subjected to excessive pressures or the metal is forced out of contact by substances accidentally entering into the joint during driving. In cases where leaks develop, they may be stopped in the majority of cases by pouring the joints full of fine steam cinders. Fine cinders should also be sprinkled in the water just outside the piling. The water seeping in between the piles will carry the finely powdered cinders with it into the cracks and gradually clog them. In tidal regions, the rise and fall of the tide will cause the water pressure against the piles to vary. With changing water pressure, the cinders loosen and fall from the joints so that a new sprinkling of cinders is usually needed with each tide.

While the use of steel sheet piling successfully prevents the entrance of water through the sides of an excavation, it cannot in any way interfere with the passage of water up through the bottom of the excavation. Usually, the water coming up through the bottom can be intercepted easily and led away by an intelligently planned system of drains. The drains should empty into one or more sumps from which the water can be pumped out of the excavation.

Arrangement of Piling.—A drawing should be prepared showing the intended arrangement of piling and timber bracing. It

should consist of a plan with necessary sections. The scale of the drawing should be large enough to show details clearly. A scale of ½ inch equal to 1 foot will be found satisfactory.

The plan should show the outlines of the foundation to be constructed and the position of the sheet piling. The exact number of piles on each side of the excavation should be shown, the number being computed from the effective width of the pile section to be used. The corner piles occupy a space on each side equal to one-half the width of an intermediate pile; for example, the corner pile for an 8½-inch straight section measures 4¼ inches along each side. Corner piles are made in two shapes to

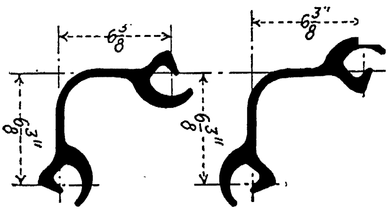


FIG. 38.—Rolled corner sections.

suit the position of joints at the corners, as the corner piles are not reversible. As may be seen from an inspection of the pile sections, the use of an odd or even number of piles on a side decides which style of corner section is used.

The sheet piling should be kept 3 or 4 feet outside the foundation walls so that the concrete walls are clear of the piling and so that space is provided for drains between the concrete forms and the piling to care for leaks or seepage. This space also provides room for a sump in any location thought desirable.

Design of Timber Bracing.—The sizes and positions of all timber walers and braces are shown on the drawings (see Fig. 39). The sizes of timbers to be used and their positions should not be arrived at by guessing, but a careful design based on computations of strengths and proper locations of timbers should be followed.

The pressures that will come upon the piling should be first computed. These will vary with the depth below the surface and with the distance below the water line.

The resistance of a sheet pile to bending stresses should first be ascertained. Its strength regulates the distance vertically which may be permitted between walers at various depths. The

top of the sheet piling should preferably be kept slightly above the surface of the ground. The distance to which the foot of the piling should extend below the bottom of the excavation will vary with the nature of the soil. Ordinarily, a distance of 4 feet will prove suitable, although 10 or 12 feet may be needed. About one-half the depth of water will be suitable in many cases.

In designing the timber supports for the steel sheet piling, it should be remembered that the timbers must be strong enough to

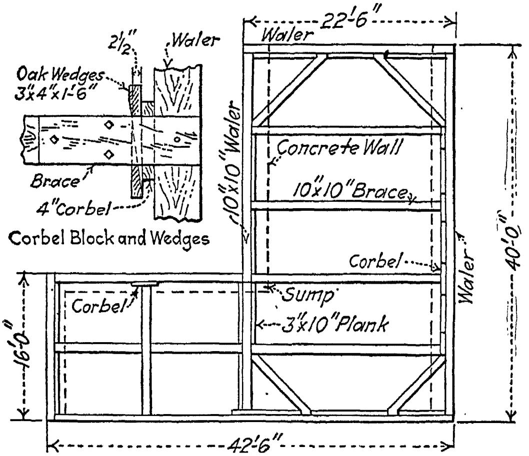


Fig. 39.—Example of timbering.

carry the loads coming upon them and that they should be spaced far enough apart to provide sufficient working space between them. The arrangement should be as simple as possible. Timbers less than 8 by 8 inches should not be used, 10 by 10 or 12 by 12 being the usual sizes. For the sake of simplicity, an effort may be made to adhere to one size of timber throughout, although such an attempt should not be carried to extremes.

If a grab bucket is used for the excavating, the cofferdam bracing should be of heavy design to withstand the jars and strains occasioned by the bucket striking them. Attention should be called to the knee braces shown in the plans of cofferdam bracing in Figs. 35 and 39. The knee braces support the end walers against bending and make it possible to omit several lines of longitudinal braces.

Design of Walers.—The size of each waler will depend on its strength as a beam acting with a length equal to the distance between braces. The vertical distance between the walers should be as great as the ability of the sheet piling to resist side pressure will permit. The walers usually may be spaced vertically anywhere from 5 feet upward. The greater the depth below the surface the closer this spacing should be.

Design of Braces.—The bracing should consist of timbers of the same size as the waler timbers if possible. In designing them

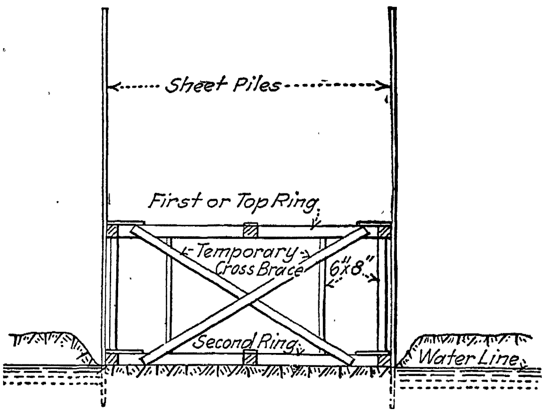


FIG. 40.—Timber guide for sheet piles.

they should be computed as columns with a length equal to the distance across from waler to waler. This unbraced length should not be permitted to exceed forty times the least side of the timber. The length of braces should preferably be between twenty and thirty times the least side. In plan, the braces should be spaced 8 to 12 feet apart to provide ample working space between them (see Fig. 39).

Placing Timbers.—Where steel sheet piling is to form an inclosed cofferdam, it is necessary to make sure that the piles will be driven in a strictly vertical position. To make sure of this, the piles should always be arranged around a structure formed of the two upper rings of timbers. The second ring of timbers should be placed on the ground with the top or first ring supported above it on 6- by 8-inch posts (see Fig. 40). All braces should be installed in both rings and the structure should be braced by temporary vertical cross-bracing. This provides a structure around which the piles may easily be set plumb.

The piles are driven down until the hammer strikes the top ring of timbers. Excavation must then be started and sufficient material must be removed to permit the timbers being forced down to their permanent positions. This can best be done with the aid of the pile hammer. The piles then are driven down all the way and excavation is resumed.

The actual work of construction should start with the placing of walers. The line of the outside surface of the timbers should be staked out on the ground. The waler timbers should then be cut, framed and placed in position. They should be laid exactly level at the correct elevation. When the completed ring of walers is in place, the braces should be cut and installed. The braces should be cut a few inches short of the entire distance between walers to provide space for large hardwood wedges to be driven between one end of the brace and the waler or corbel block. These wedges bring the braces to a snug bearing and are primarily inserted to facilitate the removal of the timbers later. A corbel block twenty inches long should be spiked against the side of the waler opposite one end of each brace. The corbel provides clearance for driving the wedges and aids removal of braces (see Fig. 39).

A scab of 2-by-10 plank about 3 feet long should be spiked across the tops of each brace and waler to support the brace and prevent displacement. If a bucket and derrick are to be used, the scabs should be made of 3-inch planks bolted to the timbers with bolts $\frac{3}{4}$ inch in diameter.

The entire weight of the timbers may be supported by chains or steel cables wound around the bottom waler and hung by hooks from the top of the steel sheet piling or the bottom waler may be supported from the bottom of the excavation by posts. In all cases, however, posts of 6 by 8 or stouter timbers should be cut between each ring of timbers to support the upper rings.

Placing the Steel Piles.—The placing of the steel sheet piles should be started at one corner by the placing of one of the corner piles. The corner pile should be stood in place and carefully plumbed and stayed. The adjacent pile may then be placed. It is preferable to place all the piles around the entire perimeter of the excavation before any driving is done, but where it is desired to save time, the driving may start as soon as the piles on one side of the excavation have been installed.

Each succeeding pile must be lifted above the top of the one previously placed, inserted in the joint, and dropped into place. This operation will usually necessitate the use of a gin pole or a derrick. The height of pole necessary may be reduced by digging a trench down to the water along the line of the piling. To facilitate removal later the joints of each pile should be well lubricated with a heavy grease.

While the piling plan should be prepared showing the number of sheet piles on each side of the excavation, the piles will either overrun or underrun the exact positions computed by using the theoretical widths of piles unless extraordinary precautions are taken to prevent it. Thus there will usually be a change from an odd to an even number of piles or *vice versa.* This will change the type of corner pile needed. For this reason, additional corner piles of each type should always be provided. Where the piling packs out beyond the outside of the walers, filler pieces of wood may be inserted between the waler and the sheet piles, extending 5 or 6 feet from the corner. The filler piece is needed only at the corner, as the flexibility of the pile joints permits the rest of the piles to come in against the waler.

Driving the Piles.—Steel sheet piles may be driven with either a drop hammer or some variety of steam hammer. The steam pile-driving hammer is most frequently employed, as the apparatus from which it is suspended can usually be moved more easily around all portions of the excavation. A drop hammer to be employed efficiently usually requires a guide frame and other clumsy supports.

The Hammer.—The size of the hammer selected for the work should be suited to the weight and size of sheet pile to be driven. The nature of the driving, whether easy or difficult, as well as the depth to which the piles must be driven, should all be taken into consideration in making a correct selection. A considerable portion of the time required in sinking sheet piling is occupied in shifting the apparatus; thus it is desirable to use as light a hammer-driving rig as can perform the work efficiently. There is also considerable advantage in the difference of purchase price in favor of a light hammer.

Power.—The so-called "steam pile-driving hammer" can be operated equally well by steam and compressed air. When steam is to be employed, an experienced fireman and some kind of a portable steam boiler is necessary. Compressed air provides a

clean and easy source of power.. The compressed air may be furnished by a portable compressor driven by either electricity or gasoline. Care must be taken in providing either steam or compressed-air power to see that a generous surplus of power is furnished over that indicated by theoretical requirements.

Suspension of Hammer.—The pile hammer may be hung from the boom of a derrick if one is in use on the work, otherwise a gin pole or a "dutchman" can be erected and the hammer can be hung from the top of it. A gin pole can be best operated from the inside of the inclosure and may be moved about on planking laid on top of the timber braces. A dutchman can be best operated on the bank outside the excavation. If placed inside the lines of sheet piling, difficulty will be experienced at the corners by interference between the sheet piling and the inclined braces on the dutchman.

Driving Piles.—The operation of driving the sheet piles with a steam hammer is a simple one. A gang of three or four men will usually be sufficient. One man operates the valve on the steam hammer, the others tend the suspension tackle and the guy lines. The hardest part of the driving lies in moving the pole about and in raising the hammer. When a heavy hammer is suspended from a revolving crane or derrick boom, this work is done by the machine. In driving with a light hammer suspended from a pole, the hammer is hung on a tackle and hoisted to the top of the pole in preparation for driving. As the driving progresses, the hammer is gradually lowered by the tackle so as to rest always on the top of the pile. When the pile has been driven, the pole is moved, the hammer is raised again to the top of the pole, and driving is started on the next pile.

Pulling Sheet Piles.—After the work for which the sheet piles were driven has been completed, it is usually considered desirable to pull out the piles. The most economical way of pulling steel piling is by means of a harness of wire rope placed about an inverted steam hammer and attached to the top of the pile by a pin and flat plates, the process of driving being reversed. With this rig hung from the boom of a revolving crane or a derrick only one or two men are required and little labor need be expended in moving the apparatus about. The cable of this rig does not last long when pulling heavy piles and several additional lengths of cable should be kept on hand.

The inverted hammer may also be used, hung from a gin pole, as when driving the piles, or the piles may be pulled out by means of a chain block or by a tackle of wire rope operated by a winch. The chain block or tackle may be hung from a gin pole high enough from the ground to clear the tops of the piles when lifted to the highest position.

In pulling steel sheet piling the first pile will usually be the hardest pile to move. Frequently, a pin inserted in a pulling hole in the top of a pile will tear through the thin metal of the pile web. In such cases an additional hole should be cut in the pile so that the pulling tackle can be attached in more than one hole.

A rigging for pulling small piles quickly may be had by suspending a 5-ton chain block from a pole by means of a single wire-rope block rigged so that there are two parts to the tackle. The pile is first pulled by the chain block. As the pulling becomes easy, the tackle is used to pull it the rest of the way.

In deciding upon whether the sheet piles are to be handled with a gin pole or a crane or a derrick it should be borne in mind that a gin pole should give the lowest operating costs. With a pole the main expense is the wages of a gang of about four men. If a crane is used there will be about an equal amount of wages and also the charges for the crane.

CONTROLLING WATER

Controlling Water.—In excavating, water may be encountered at varying depths below the surface of the ground. The depth of this ground water will depend a great deal upon the location. The ground water will be met with at about the level of the nearest river, creek, or other natural drainage channel in localities where the surface of the ground is comparatively level (Fig. 41). Usually its elevation will be slightly above the surface of the water-course. Along the coast the ground water will be found at about high-tide level and its depth will fluctuate slightly with the tides. In hilly country the ground water will be found on a level with the drainage courses in the valleys and at higher levels on the hills, following the general contour of the ground, as indicated in the diagram in Fig. 41.

When an excavation is carried to the depth at which ground water is encountered, the latter, unless adequate means are provided for controlling it, will seep into the excavation, turn the

subgrade into a soft mud, and interfere with the work generally. When the inflow is in sufficient quantity, it may even fill the excavation overnight to such a depth as to cause a suspension of operations.

Where the sides of an excavation are to be sheet piled, the inflow from the sides may be greatly lessened by the use of either splined or tongue-and-grooved sheeting. Where the inflow is considerable, a sheeting made of three planks, as in Fig. 42,

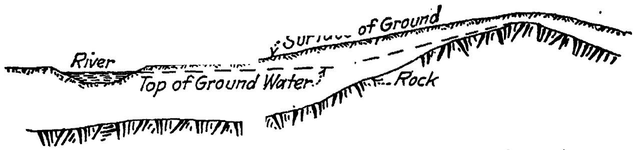


FIG. 41.—Relative positions of ground water and surface of ground.

may be employed or steel sheet piling may be used. The last two methods are comparatively expensive and it will usually prove less costly to use ordinary tongued-and-grooved sheeting

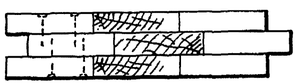


FIG. 42.—Sheet piles, triple thickness.

and adopt adequate measures for handling the water after it has forced its way through the joints of the sheet piling. In almost all cases the water will not be entirely excluded by the sheet piling, and provision must be made to intercept it and to lead it away. Where the problem of excluding the water is a serious one and where the depth is sufficient to cause heavy pressures on the piling, the use of steel sheet piling will usually prove justifiable.

The quantity of water which comes up through the bottom of the excavation may be lessened by digging a sump well below the bottom which will serve to lower the water level there. As the digging progresses to greater depths, the sump should be correspondingly deepened, so as to be at all times considerably below the level of the bottom of the excavation. All water seeping through the sides of an excavation or all that has worked past the sheet piling should be lead through drainage channels cut in the earth to this sump from which it can be pumped to the surface.

In digging trenches for pipes, the water can be led into a sump in the bottom of the trench and pumped out. When laying sewer

or drain pipe, the drain may be laid working up grade and the water may be allowed to run off through the drain already laid.

In more important work a subdrain may be built in the bottom of the trench to carry off the water to sumps placed at intervals. These drains may be formed by tile pipe laid with open joints, by a box drain made of planks, or by a channel dug in the subgrade

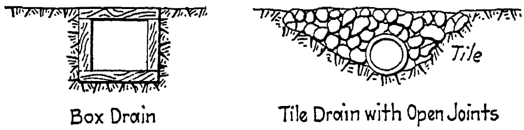


FIG. 43.—Drains for excavations.

and filled with loose stones. These drains are shown in cross-section in Fig. 43. The sides of the box drain may have holes bored in it to allow the water to enter or the top or bottom planks may be omitted to suit conditions. The tile drain is laid with muslin or cheesecloth wrapped around the open joints.

Drains and Sumps.—Drains inside a cofferdam should be arranged so that the water runs over the side. An open drain is best. An effective way of building it is

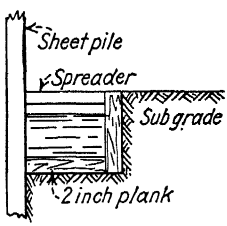


FIG. 44.—Drain in a cofferdam.

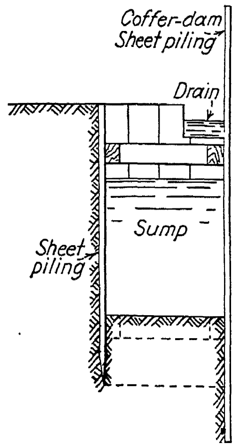
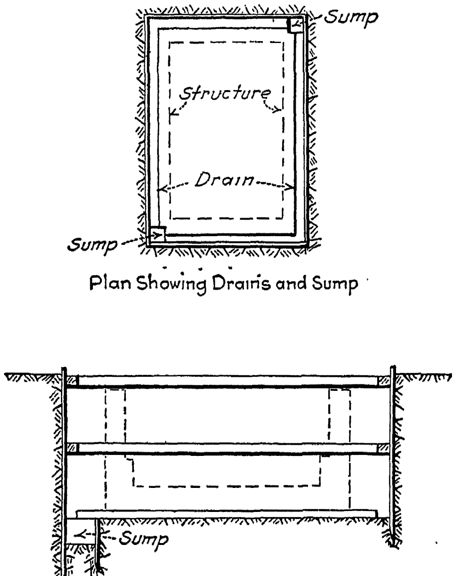


FIG. 45.—Typical sump.

shown in Fig. 44. The sheet piling forms one side of the box. The other side and bottom are preferably made of 2-inch planks. A drain of this design can be easily cleaned with a shovel.

A sump should be designed to let the water flow into it over the top edge. It should be deep, so that the pump suction can be kept clear of the earth in the bottom of the sump and at the same time provide sufficient capacity to keep the suction covered with water. A large pump will require a sump of large capacity, although the dimensions will also be affected by the rate at which water will enter it.

A sump can be made of plank sheet piling driven into the ground and suitably braced. In important work, it will be found advantageous to make the sump large enough to enable a man to enter and clean it with a shovel, as quantities of earth or sand may be carried into it. The greater quantity of water entering a sump will enter it from the drains and over the top edge, but in some soils a portion of the inflow will enter the cracks between the sheet piles. Very often this is undesirable, as sand or earth



Plan Showing Drains and Sump

Section Through Drains and Sump

FIG. 46.—Drains and sumps.

will be carried in by the water. This condition may be dangerous in cofferdam work, particularly where nearby foundations might be undermined. A typical sump is shown in Fig. 45.

A good sump for a small job may be made of a steel cylinder forced down into the bottom of the excavation. The cylinder can be a steel drum or a piece of steel pipe of large diameter. The water should enter over the top edge. Holes in the sides of the cylinder are not desirable, as sand or earth will enter the sump through them and will require frequent cleaning of the sump.

A Blow-in.—When the excavation inside a cofferdam has progressed to a depth of several feet, difficulty may be experienced

from the earth rising in the bottom of the excavation and partially filling the space inside the sheet piling. If the excavating is done through water-bearing soil, the movement of the earth will frequently be accompanied by the appearance of large springs of water coming up through the bottom (see Fig. 47).

A blow-in of this character is caused by the unbalanced pressures of the materials outside and inside the sheet piling. A blow-in may occur where the sheet piles have not been driven to sufficient penetration below the subgrade. A small penetration does not provide enough resistance against outside pressures. If the penetration is shallow, the pressure on the exterior may push the sheet piles in at the bottom unless a lower ring of timbers is installed.

A blow-in may also be caused by water seeping upward inside the cofferdam with sufficient velocity to displace particles of sand or earth in the bottom of the excavation. This movement in the bottom of the excavation may increase and extend until it becomes a run, carrying the earth under the ends of the sheet piles, bending the sheeting inward at the bottom, and filling the interior of the cofferdam with earth and water.

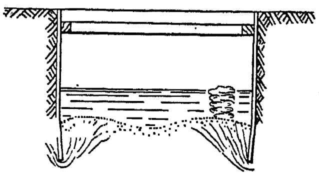


FIG. 47.—A blow-in.

The sheet piles should extend well below the subgrade so as to be supported against any pressures tending to push them inward at the foot. A bottom ring of timber bracing should be inserted, as far down as possible, if there is any doubt as to whether the piles are extended deep enough.

Any displacement of particles of earth or sand by inflowing water can be stopped by dumping crushed stone into the subgrade close to the sheet piling. Crushed stone 1½ or 2 inches in diameter will usually prove too heavy to be moved by water flowing up through the bottom. Bags filled with sand or gravel may be used for the same purpose.

When an excavation is carried down through sand, trouble may be experienced from large quantities of water rushing up through the bottom of the excavation. If there is an underlying bed of clay, the sheet piles should be driven down into it, so as to cut off the flow. If the entire substratum consists of coarse sand, the quantity and velocity of the inflowing water will not

be affected appreciably by resorting to sheet piling of extremely long lengths.

Where the water enters in great volume and with high velocity, it will usually boil up through the subgrade in the form of large springs, sometimes 5 or 6 feet in diameter. This inflow can be handled best by a system of well-points driven well down below the subgrade. The bottom of the area can be covered with crushed stone, and all water not stopped by the well-points can be led away along the piling into sumps and pumped out. Where the quantity of water is affected by the rise and fall of the tide, it will be found advantageous to do most of the work during the intervals of low tide.

Money and effort are often wasted in pumping water to keep an excavation dry for depositing concrete when the work can be done just as well by depositing the concrete under water. It is best to let the water rise to full depth when concreting under water, as the pressure will check the velocity of inflow and the concrete can be deposited in quiet water.

The floor slab of any water-tight structure, surrounded by water, should be heavy enough to resist the lifting pressure of the water. Basement floors in water-tight cellars are occasionally lifted and cracked in the center by water pressure. A concrete floor in such a structure must either be of sufficient thickness to counterbalance the water pressure by its weight, or it must be reinforced with steel to resist the bending stresses. In the latter case, sufficient weight is derived from the masonry of the walls to keep the structure from floating.

Pumping.—The methods used for removing the water from an excavation will depend not only on the quantity of water to be handled, but also on the height to which it is necessary to lift it. In the ordinary cases of trench or foundation excavation, a pump placed on the surface of the ground which will lift the water by suction from a sump in the bottom of the excavation is all that is requisite, the water emitted by the pump discharging by gravity into natural drainage channels. For this work any type of pump may be used. The diaphragm trench pump, either hand operated or driven by gasoline engine, is most commonly employed where the quantity of water to be pumped is not too large. The centrifugal pump is the most popular type for pumping large volumes of water and may be obtained to run by steam power or by electricity.

In excavations which exceed 18 or 20 feet in depth, which is about the practical limit of depth from which a pump will lift water by suction, it is necessary to use pumps of a type which will be able to force the water up through a discharge pipe to the desired height above the bottom of the excavation. This means that the pump will have to work against a constant pressure in the discharge line equal to the weight of water in that pipe. Ordinarily, the pump is placed upon a platform or stand resting on the bottom of the excavation or close to it, and the discharge pipe connected to it is extended up to the surface of the ground. A centrifugal pump is well adapted to this work as is also any type of reciprocating pump. Several styles of pumps are manufactured which may be hung in an excavation from supports overhead.

Pumps.—The height of suction to be recommended for a centrifugal pump is about 15 feet; reciprocating pumps can be given a suction length of 20 feet with good results. It should be understood that a pump will pump more water with a short suction than with a long one. This principle can be utilized to advantage when increased capacity is needed, as it is often possible to move a pump to a lower level and to secure a shorter suction with greater quantities pumped. Centrifugal pumps will stop pumping when air gets into the suction. A reciprocating pump will pound under the same conditions.

A centrifugal pump has to be primed with water before it will pump. Also, it is always desirable to have the discharge pipe extend upward a foot or two above the pump, so that the impulse given to the water in the pump does not break the suction. If the discharge pipe must extend horizontally from the pump, a gate valve can be inserted at the discharge end. The valve should be kept closed when starting, until the pump has built up a pressure, and should then be opened. When a pump is pumping more water than is flowing into the sump, the output can be cut down by closing the valve partly.

A reciprocating pump will start without priming and will pump air and water alternately and pass extraneous matter through the valves. For these reasons a single-cylinder, double-acting piston pump will always be popular. The cylinder lining of a piston pump is eventually destroyed by the grit in dirty water. A pump lining consists of a thin cylinder of metal. It can be removed and replaced by a new one without much labor.

Testing Bearing Power of Subgrade.—It occasionally happens that, when the excavation has been carried to the final depth, the constructor finds it necessary to make a test of the bearing capacity of the soil. This may be accomplished readily by building a device, as shown in Fig. 48. It consists of a platform resting on a short post with a cross-section preferably 1 foot square. Stakes should be driven firmly into the ground on all four sides and braced to secure the platform against overturning.

The platform when in position is loaded gradually and measurements are taken as the loading is increased to determine its vertical position relative to a fixed mark near by, until settlement

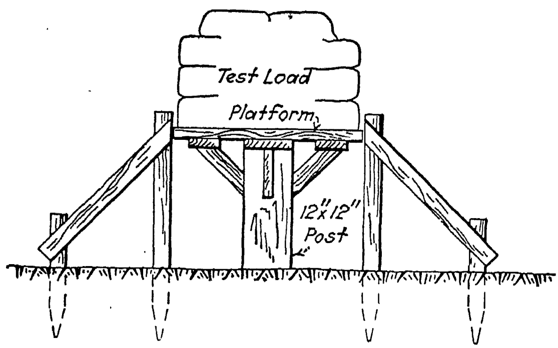


FIG. 48.—Testing bearing power of subgrade.

is noticeable or the requisite loading has been exceeded by a comfortable margin without causing settlement. The loading should not be increased at too short intervals; 4-hour periods or 24 hours should be allowed to elapse according to the delicacy of the test. It is advantageous to make the cross-section of the post equal to an area of 1 square foot, as the pressure on the soil per square foot is then equal to the load on the platform.

Test Borings.—Previous to designing the foundations for a structure, it is usually desirable to investigate the nature of the soil upon which the structure will rest and to ascertain the character of underlying strata and the depth below the surface at which any changes occur. The conditions that exist to a depth of 10 or 15 feet can be revealed by digging test pits at selected locations on the site. For greater depths a wash boring should be made. A boring can be put down to a depth of 50 to 60 feet with the improvised apparatus shown in Figs. 49 and 50.

A boring is made by driving several lengths of steel pipe into the ground and washing out the earth inside the pipe with water forced through a small pipe that is inserted in the larger one.

The large test pipe or casing should preferably be 1½ or 2 inches in diameter. A pipe larger than 2 inches is difficult to drive into the ground. The casing should be prepared for driving, by cutting it into 5- or 10-feet lengths depending upon the interval desired between samples. A small drop hammer can be made from a short piece of 8-inch pipe, as shown in the figure. The piece of pipe is filled with lead and the top and bottom are closed with a steel plate. A length of steel rod or pipe is arranged to pass through the axis of the hammer, projecting 3 or 4 feet into the casing so as to act as

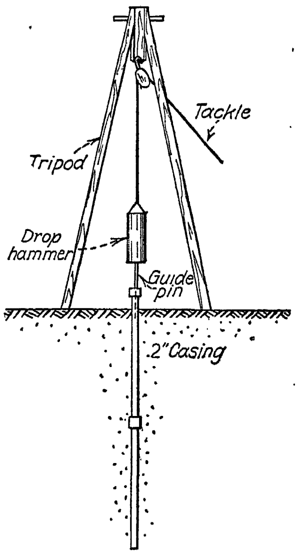


FIG. 49.—Driving the casing.

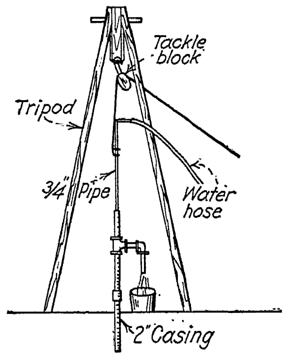


FIG. 50.—Washing a sample.

a guide to hold the hammer in line. The weight is raised by three men pulling on a rope with the tackle. The hammer is permitted to fall, striking the pipe and driving it an inch or two into the ground. The casing can be driven in this way to a depth of 50 feet with comparative ease.

A pipe coupling should always be screwed on the top end of the casing so that the hammer will strike it, rather than the pipe. The threads on the pipe are thus protected.

When a length of casing has been driven, the drop hammer is disengaged and a small pipe connected to a hose is lowered inside the casing, until it reaches the earth in the pipe. Water from a city supply or from a pump is then forced down through the

small pipe into the earth at the bottom. The water fills the casing and, flowing up and out of it, carries small quantities of soil with it. The soil washed out is caught in a pail and can be preserved as a sample of the ground at that depth.

The operation of washing out the interior of a casing and collecting the sample can be facilitated by the piping arrangement shown in Fig. 50. The arrangement of fittings shown can be screwed into the coupling on each length of pipe after the length has been driven down.

Samples may be taken without washing by driving a pipe of small diameter into the earth in the bottom of the large

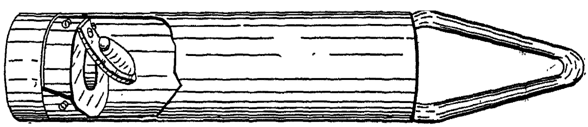


FIG. 51.—A sand pump.

pipe. The earth becomes wedged in the bore of the small pipe and can be lifted to the surface of the earth for examination.

Another method of getting samples in water-bearing soil is by means of a sand bucket shown in Fig. 51. The bucket is lowered into a casing on the end of a rope and is worked up and down until the bucket is filled with earth. The bucket is then raised and the sample is collected.

ROCK EXCAVATION

Rock excavation is commonly accomplished by exploding dynamite in holes which have been drilled in the rock for the

FIG. 52.—Hand drill.

purpose. The holes are drilled by hand drills or by drilling machines operated by compressed air or steam. The dynamite charges are usually fired by detonators exploded by an electric current.

Hand Drilling.—The drilling is usually done by hand where only a small quantity of rock is to be removed. It is best to employ two or three men on each hand drill to quicken the rate of drilling. One man holds the drill and rotates it, the other men strike the drill with sledges. As the drilling proceeds, water is

poured into the hole to keep down the dust and to absorb the heat generated by the drilling as well as to assist in throwing the dust of the drilling out of the hole.

A typical hand drill is shown in Fig. 52. The cutting edge is shaped so as to cut a hole which is slightly larger than the shank of the drill. Hand drills become dull very rapidly and a sufficient supply of them should be provided, so that sharpened drills will always be on hand while the dull drills are being sharpened. The drills may be sent to a near-by blacksmith shop to be sharpened or a small portable forge and anvil with suitable tools may be provided for sharpening the drills on the site of the work.

Machine Drilling.—Machines for drilling holes in rock are designed to operate with either compressed air or steam power. Compressed air is preferable, as it is cool and invisible. Any rock drill operated by steam is only about one half as efficient as

FIG. 53.—Jack hammer drill steel.

when operated by compressed air. Steam heats the machine and the exhaust steam is visible when the machine is operated. Compressed air is usually furnished by an air compressor run by gasoline or electric power.

The tripod type machine is made in various sizes and handles drill steels of various lengths and diameters according to the power of the machine. A hole is started with a short steel, longer steels being inserted in the machine as the hole progresses deeper into the rock. A complete assortment of drill steels varying in length by even numbers of feet, from 2 feet upward, is necessary for each tripod machine. The hole drilled by the tripod machine gradually tapers in diameter, growing smaller in bore as the depth increases. For this reason, the gage across the cutting edges of the drills varies for each length. The drilling machine gives the steel a rotating motion to prevent the steel from becoming caught in the hole. A small crank at the back end of the machine, turned slowly by the driller, causes a gradual advance of the steel as the hole is deepened. A drilling machine may be described as a wet drill or a dry drill, depending on its design. A wet drill is so designed that water can be forced through the hollow drill steel to the bottom of the hole. The

water reduces the dust of drilling, washes out chips, and reduces the heat generated in drilling.

For drilling small holes a smaller drilling machine called a jack hammer may be used. The machine is supported by the man operating it. Jack hammer drills are designed as both wet and dry machines. Normally, the jack hammer is used as a dry machine. The drill steel used with a jack hammer is hollow to

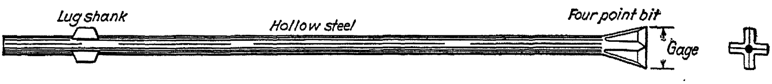


FIG. 54.—Steel for tripod drill.

permit the compressed air from the exhaust to travel down through the steel to the bottom of the hole and hence outward from the hole, carrying the dust of drilling with it. A jack steel is shown in Fig. 53. The machine gives the steel a rotating motion and the steel is struck a hammer-like blow by the interior mechanism. The length of drill steel used with a jack hammer need be regulated only by the depth of the hole drilled. One or two lengths are usually sufficient. In the wet machine, a mixture of water and air is forced through the hollow steel to the cutting face of the bit.

Position of Drill Holes.—To increase the effectiveness of blasting, the rock should be excavated by forming a face, as shown in Fig. 55, toward which the rock may be disrupted. A blast

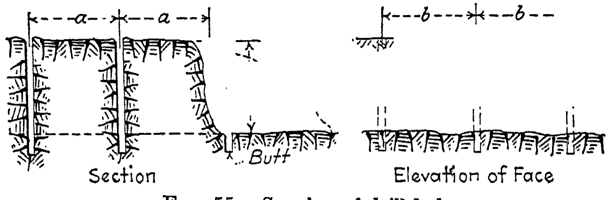


FIG. 55.—Spacing of drill holes.

when fired in a drill hole will not remove the rock to the bottom of the hole but will leave a "butt" which is usually 8 inches to 1 foot in depth. For this reason, it is necessary to drill the holes about 1 foot below the depth to which the rock is to be removed. For effective blasting the holes should be located back from the face a distance about equal to the depth of the hole, as at *a* in Fig. 55. The holes should also be spaced center to center an equal distance as at *b*.

In excavating a hole in ledge rock, the work is started by blasting a wedge-shaped mass of rock, called the "cut," out of the center of the area to be removed so as to form a free face for subsequent blasting. The holes drilled for this purpose are designated "cut holes" and are drilled obliquely, as shown in Fig. 56. Care should be taken in drilling to see that the holes do not intersect or cross before the desired depth is reached. The

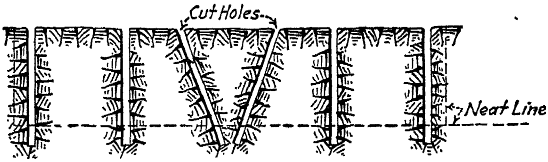


FIG. 56.—Excavating a hole in ledge rock.

remaining holes are drilled vertically in the usual manner. All the holes should be drilled and the blasting may be done in rounds. The cut holes should always be fired first, followed by each consecutive ring of holes in turn.

The ordinary run of small operations where the holes are drilled by hand will not admit of much theoretical placing of holes or proportioning of blasting charges; but the position and direction of seams should be studied and the holes should be drilled in positions where the effect of the blast will not be lessened by the position of the seam.

Ledge rock is often traversed by open seams which dip at an angle with the vertical and which will be likely to intercept the

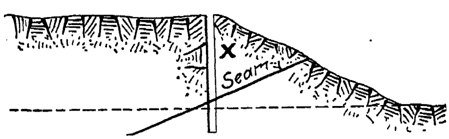


FIG. 57.—Seam intersecting drill hole.

course of the drill holes. When dynamite is exploded in a drill hole which crosses an open seam, the force of the explosion is prevented from crossing the seam. A hole drilled in relation to a seam, as in Fig. 57, will tend to dissipate the force of a blast. In Fig. 57, the shot would blast out the triangular piece X and would have little effect on removing the remainder of the ledge.

Blasting.—Dynamite is an explosive mixture of nitroglycerine and a granular absorbent. It has a yellowish color and is packed

in waterproof paper in the form of cylindrical cartridges about 1⅛ by 8 inches in size. It is shipped in boxes of 50 pounds containing about 100 cartridges. Dynamite is safer to use than gunpowder, as it is necessary to subject it to both heat and concussion to explode it. When ignited in the open air, it burns with a flame like hot oil. Cartridges or sticks of dynamite are frequently dropped several hundred feet without exploding.

At a temperature of 42°F. dynamite stiffens and becomes hard and is then in the condition known as frozen, in which state its character is entirely changed. When frozen, dynamite is dangerous to handle and is likely to explode if jarred violently.

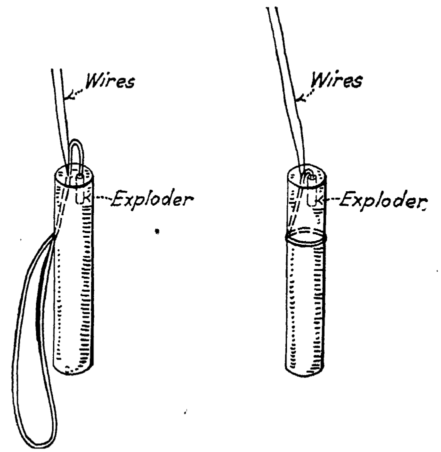


FIG. 58.—Method of forming priming cartridge.

When thawing it, great care should be exercised not to subject it to direct heat or to attempt to thaw it quickly. It should preferably be placed in a warm room where it will thaw slowly. Thawing kettles using hot water may be used for thawing small quantities. When a large quantity of dynamite has to be stored in cold weather, it should be housed in buildings of special construction, which have been designed so that the dynamite may be kept warm without danger of explosions.

A charge of dynamite is usually made to explode by means of a small cylindrical exploder or detonator inserted into one of the dynamite cartridges of the charge. In practice, this detonator is called an "exploder" and the cartridge of dynamite with the detonator inserted is called a "primer." The detonator or

exploder is a small copper cylinder about ¼ inch in diameter, containing a quantity of fulminate of mercury and attached to the ends of two lengths of copper wire covered with a waterproof insulation. An electric current is used to fire the fulminate of mercury in the detonator which, when it explodes, causes the dynamite to explode.

A priming cartridge is formed by inserting an electric detonator into a dynamite cartridge. The best way of doing this is shown in Fig. 58. A common method is to insert the cylinder of the detonator into the side of the cartridge and to secure the wires to

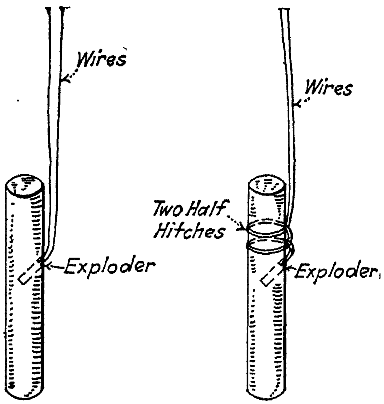


FIG. 59.—Method of forming priming cartridge.

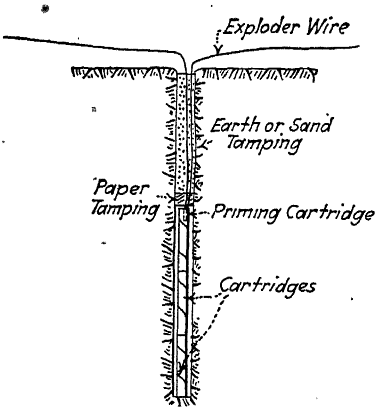


FIG. 60.—Drill hole loaded for blasting.

the cartridge with two half hitches (Fig. 59), but this is not as good a way as that shown in Fig. 58.

In the former method (Fig. 58), a hole is punched in the center of the end of the cartridge with a slanting direction so that it comes out at the side 2 or 3 inches from the end, the looped portions of the exploder wires are then passed through the hole and looped around the cartridge, as shown. Another hole is then punched in the top a little to one side of the first and straight down. The exploder is inserted in this last hole and pushed down as far as possible. The looped wires are drawn up tight around the cartridge. This forms a primed cartridge in which the wires do not cross each other at any point and which will hang vertically when it is loaded into a drill hole.

A blasting hole is loaded by inserting the cartridges into the hole, one at a time, and pressing them firmly to the bottom with a wooden tamping stick (Fig. 60). The primer cartridge should

always be put in last so that it will be on the top of the charge. When the necessary quantity of dynamite has been put into the hole, 2 or 3 inches of wadded paper should be packed into the hole on top of the dynamite and the remainder of the hole should be filled with earth tamping. The paper tamping may be omitted, but it is useful in cases of misfires, when the earth tamping can be removed down to the paper without disturbing the primer. When the drill hole is smaller in diameter than the cartridge, the latter may be broken open and small pieces of the cartridge packed into the hole.

No exact rule can be given as to the size of the charge of dynamite to be used in any case. When the blasting is done in open

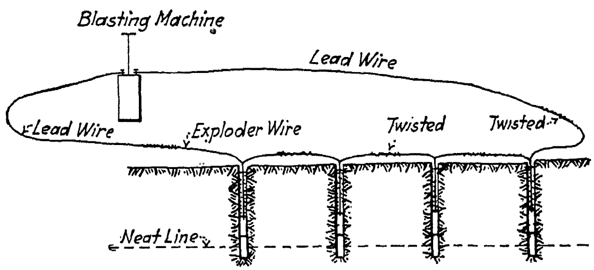


FIG. 61.—Blasting a round of holes.

spaces where no damage is likely to be done to property or to persons, a hole may be loaded slightly less than one-half full of dynamite, the remainder being filled with tamping. When careful blasting is necessary, half a cartridge may be used in small holes. The best way is to make one or two trial shots using light loads to determine the correct amount of explosive to employ.

If the explosive is properly proportioned to the amount of work it has to do, the blast will make very little noise. A loud explosion indicates either a too heavy charge or that the holes are not spaced properly to give the dynamite a maximum amount of work to do. Heavy loads break the rock into small pieces suitable for handling with shovels. If it is desired to break the rock in large pieces light charges should be used. Approximately 2 pounds of dynamite are required to blast out 1 cubic yard of ledge rock in open cut excavation and 5 pounds for 1 cubic yard in tunnels.

A typical arrangement for blasting simultaneously with a series of holes is indicated in Fig. 61. It will be noted that the

exploder wires are twisted together in series, as likewise the end exploder wires together with the lead wires. The wires connecting to the blasting machine form a complete closed circuit for the electric current.

Before twisting the ends of the wires together, the insulation is removed with a knife and the wires are scraped clean and twisted tightly together, in the manner shown in Fig. 62, to insure contact for the electric current. To twist the wires together properly, the bare ends of the wires should be crossed and each end twisted around the other wire. The electric current for firing the blast may be furnished by an ordinary lighting circuit or generated by a special blasting machine, as indicated in Fig. 61.

The lead wires should be long enough to enable the person who operates the blasting machine or electric switch to stand outside

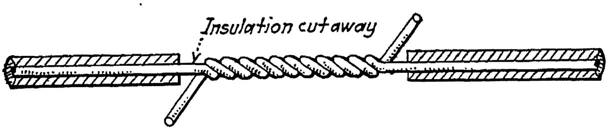


FIG. 62.—Method of connecting exploder and lead wires.

the danger zone. The lead wires should never be connected to the blasting machine until it is time to fire. When the blast is ready to be fired, the rack bar of the blast machine is lifted up and then pushed downward with a quick hard stroke to the bottom of the box. This downward stroke generates a current of electricity which fires the blast.

Misfires.—In the case of misfires, when using electric blasting exploders, it is generally safe to investigate the trouble immediately. The lead wires should be disconnected from the blasting machine and either faulty electric connections or short-circuits should be sought. If the cause of the misfire is found, the wires are reconnected and the blast is fired. If it is impossible to find the trouble, the tamping may be removed from the hole almost down to the charge and a new primer cartridge may be inserted. The hole should then be filled with tamping and fired with the new primer.

Blasting Mats.—When blasting in the neighborhood of buildings or where many men are at work, some provision usually is necessary to prevent broken fragments of rock from being hurled about the vicinity by the blast. To this end, the loaded holes

should be covered with a mat of some kind. A mat of woven rope is convenient to use for this purpose, because being flexible it conforms to the surface of the rock and possesses sufficient weight to prevent its being thrown through the air by the blast.

An admirable substitute for a rope mat may be made, as shown in Fig. 63, out of a mass of tangled wire weighted down with logs and chains. A considerable quantity of wire is required for this sort of mat. The mass should be weighted with logs at least 6 inches in diameter. Two chains should be used, each long enough

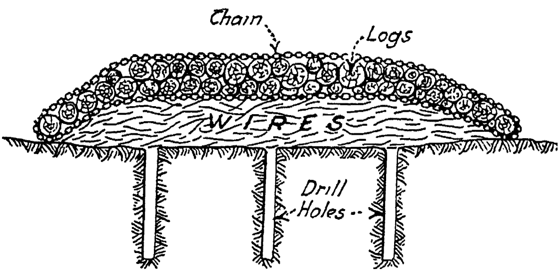


FIG. 63.—Wire mat weighted with logs and chain over blast.

to go completely around the pile of logs. The chains should be heavy, of at least ⅜-inch stock.

When the holes have been loaded and the exploder wires connected with the lead wires, the wire mass is rolled over the holes and the two chains are stretched across it. The logs are then thrown on the pile and the chains brought up around them and the ends are tied together. The blast may then be fired with little danger to its surroundings from flying rock.

Removing Blasted Rock.—The spacing of the drill holes and the size of the explosive charges used have a direct effect on the sizes of the fragments of rock resulting from the blast and on the methods that are necessary in removing them. Heavy charges of explosive and close spacing of drill holes will result in a product which is broken into small pieces and which can be shoveled readily into wheelbarrows or thrown into ordinary dump carts.

Where it is necessary to be careful in regard to the strength of the blasting charges employed, the rock will usually be shattered into large pieces which will have to be pried loose with bars and will require the services of more than one man to lift them. Such pieces may be rolled onto a stone sled made of plank and

dragged away by a team or they may be loaded onto low-built platform trucks. Where such means of transportation are not suited to the requirements of the work the blasting should be done with closely spaced drill holes and light charges so that a more finely divided product will be obtained.

Round-pointed shovels should be used for shoveling broken rock. A pick for use on broken rock should have short points. Rock picks, manufactured for this particular purpose, may be procured or ordinary earth picks which have been worn down by use and repeated sharpening will give good service.

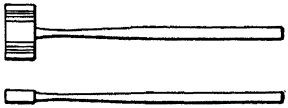


FIG. 64.—Sledge for breaking rock.

The wheelbarrows used for rock excavation should be of the all-steel type as wooden handles and frames are soon broken and racked to pieces by the rough work.

A sledge weighing 16 to 20 pounds may be used for breaking large pieces of rock into sizes which can be handled readily. The striking face of a sledge intended for this work should not be circular but should be elongated in the direction of the handle, as shown in Fig. 64. A blow from a sledge having a circular striking face is distributed radially in all directions. A blow from a sledge with an elongated striking surface is directed in a line across the stone. The handles for such sledges should be slender so that the resiliency of the handle will absorb most of the shock of the blow.

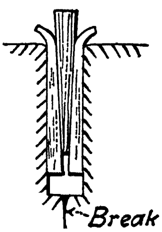


FIG. 65.—Plug and feathers for splitting rock.

Plug and Feathers.—It is often necessary to excavate ledge rock or remove old concrete machine foundations in locations where the use of explosives is impossible. Under such conditions the plug and feathers (Fig. 65) may be resorted to as an alternative method to blasting. The plug and feathers are useful also for splitting boulders or trimming any rock which may project into a trench.

A set of plug and feathers consists of a wedge-shaped plug and two specially shaped pieces of steel called "feathers." The feathers are fashioned from half round steel so as to conform to the curved surface of the drill hole. The surfaces which are turned toward the plug are flat and beveled to fit the wedge-shaped plug. The upper ends of the feathers are curved out-

ward to prevent them from dropping to the bottom of the drill hole when they are being inserted with the plug.

The holes may be drilled by hand drills or by machine, as sets of plugs and feathers may be obtained for holes of different diameters. To split rock or concrete, several sets are usually necessary. A number of holes are drilled in the rock on a line and slightly deeper than the length of the feathers. A set of plug and feathers is then inserted into each hole. The plug in each hole is then, in succession, gradually driven home with a hammer until the stone is split. The plug, being wedge shaped, presses outward against the feathers resulting in a wedging action which will not fail to split the hardest rock.

Pavement Breaker.—Concrete can be removed most quickly and economically with a pavement breaker. This tool is also known as a "concrete buster." It is operated by compressed air. The pavement breaker operates in a similar way to a small machine chipping hammer. When used to remove concrete, it should be manipulated so as to chip off pieces of concrete, always directing the point of the chisel toward a free face from which the concrete can be chipped off. If the point of the chisel is directed deep into the bulk of the concrete, very little progress can be made.

CHAPTER III

PILE DRIVING

Piles.—The principal woods used for piling are yellow pine and spruce. Piles made from hardwood trees, such as white oak and red oak, beech and ash are also used. The hardwood piles are useful where the driving is hard, as in sand or gravelly bottom. Spruce piles are used in mud and silt, where the driving is not so hard. Formerly spruce piles were in general use but they are being surplanted by yellow-pine piles from the south. Yellow-pine piles may be used where the driving is hard as well as in mud and silt.

Timber piles are most subject to decay at the water line where they become alternately wet and dry. The portion of a pile which remains continuously immersed in water does not decay and lasts practically forever. When piles are used in foundations, they should be cut off at the low water line so that they will always be covered in water. When foundation piles are cut off in this manner they are usually capped with a slab of concrete.

Timber piles need very little preparation for driving. The piles are driven with the bark on. It is usual to point the small end roughly with an axe. It is usual also to saw them to the desired length. Piles derive their supporting power principally from what is called "skin friction," that is, the friction of the ground on the outside surface of the pile. When driven in mud, the skin friction constitutes the only support for the pile. In sand, there is also the pressure on the end of the pile causing the latter to act as a column. Often, piles are driven through mud or silt until they penetrate down into a bed of sand below. The sand in such a case furnishes a considerable support for the pile. In important work, it is often desirable to drive a test pile and to load it with a test weight to determine the exact load at which the pile will settle. The results will vary in different soils.

One test with which the writer is familiar showed settlement at a load of 8½ tons with a pile 30 feet long driven in mud and silt. Another test for a pile 45 feet long driven into ground

formed of alternate beds of sand and fine clay began to settle when subjected to a load of 30 tons.

Piles are usually spaced 3 or 4 feet apart center to center. They may be spaced further apart if desired. The closest spacing allowable is around 2½ feet on centers. With closer spacing, the driving of a pile will cause those previously driven to crowd up out of the ground.

The depth to which piles are to be driven is often specified, but more frequently it is specified that they are to be driven to refusal. The term "refusal" is a relative one and should always be defined precisely in the specifications. In defining what is intended by the term "refusal," the weight of the pile hammer and the distance of its fall in feet should be specified as well as the amount of penetration under the last blow or the amount of penetration under the last few blows. In a general way, it may be said that a pile is down to refusal when a 4000-pound hammer dropping 15 feet does not give a penetration of over ½ inch. Conditions of soil vary, however, and a pile having refused to move under 10 or 12 blows will often start moving again, sinking then several inches under each blow and sometimes even 1 or 2 feet at a blow. When this condition occurs, it is frequently an indication that the pile has been broken. Piles also under frequent hammering will become "broomed" at the foot or at the head and slight apparent settlements may be due to this cause. There is a danger also of breaking the pile if the driving is continued for too long a period. Where driving is hard and there is any doubt as to the condition of the driven piles, it will always prove informing to pull out one or two questionable piles, thus disclosing beyond any doubt what condition the piles are in.

Land Pile-driving Machine.—A pile-driving machine consists, in a general way of the pile leads, the bed frame, and the hoisting engine (Fig. 67).

The pile leads is a vertical framing of heavy timbers and bracing. Its function is to form a guide for the pile hammer and to act as a guideway into which the pile may be stood upright and be maintained in that position during the driving. The top of the leads is braced by timbers running on a batter downward toward the rear and heavy hardwood knees in one piece holding the leads to the bed frame at the bottom. The top of the leads is equipped with two sheave wheels. One of these sheaves is used for the hammer rope and the other for the pile rope.

The bed frame is a simple arrangement of timbers designed to form a supporting platform for both the leads and the hoisting engine. The leads and the engine are bolted securely to the bed frame by bolts running completely through it. The under-

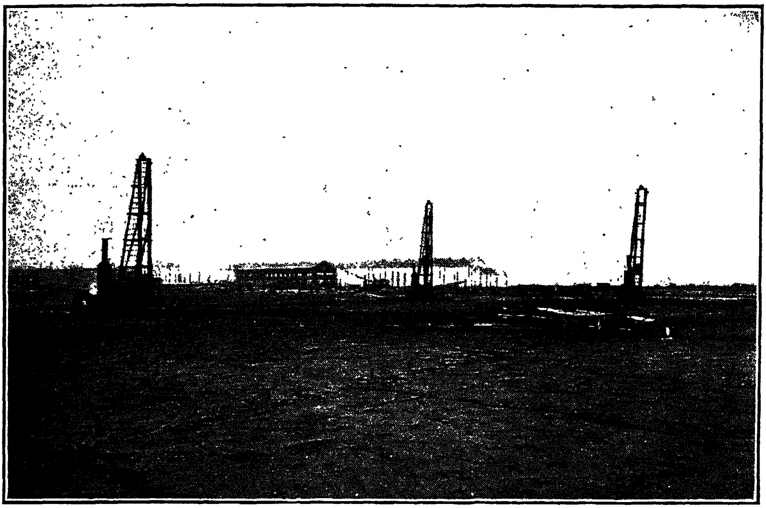
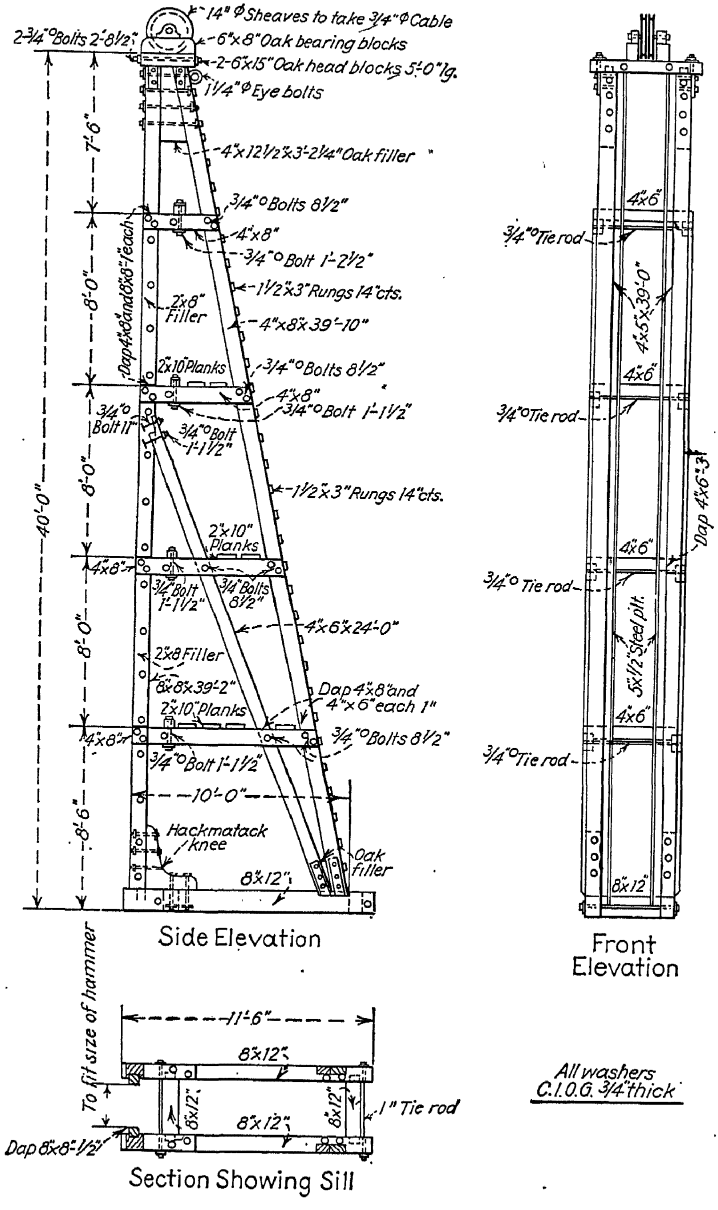


Fig. 66.—Pile driving.

Fig. 67.—Pile driving machine.

side of the bed frame is grooved out toward the front and toward the rear to provide a bearing for the rollers on which the machine is moved about.

The engine rests on the rear end of the bed frame (see Fig. 67). A standard steam hoisting engine with vertical boiler is always



40'-0" LEADS

Fig. 68.—Pile-driver leads.

employed. The engine should have two cylinders and should have two drums for the ropes. The rear drum should be used for the hammer rope and the front drum for the pile rope.

There are other parts essential to a pile-driving machine which will be described in a general way. The drop hammer is a solid block of cast iron made with grooves along two sides to engage the guides on the pile leads. It is provided on the top with an eye for fastening the end of the hammer rope by which it is

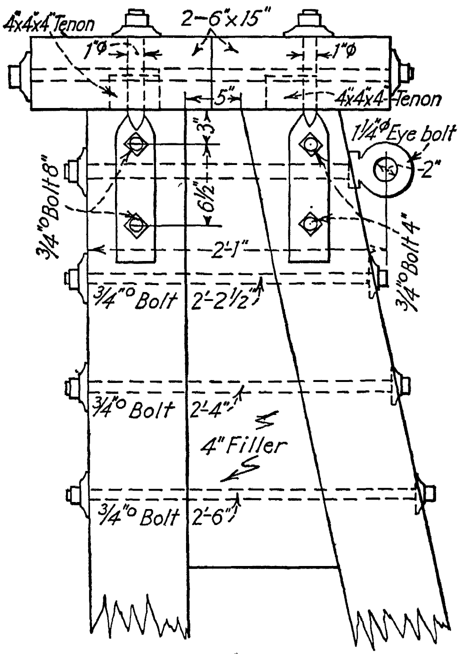


FIG. 69.—Detail at head of leads.

raised. Drop hammers are made in various weights up to about 5000 pounds. The two rollers on which the pile machine is moved about should be made of a strong hardwood, such as yellow pine. They are usually 12 inches in diameter and about 30 feet long. Plans for a pile driving leads, bed frame and rollers, will be found in Figs. 68 to 73. The distance between ways is not given as it will depend upon the width of hammer used. The leads are attached to the sills by means of hackmatack knees. This is another name for a species of pine familiarly known as the

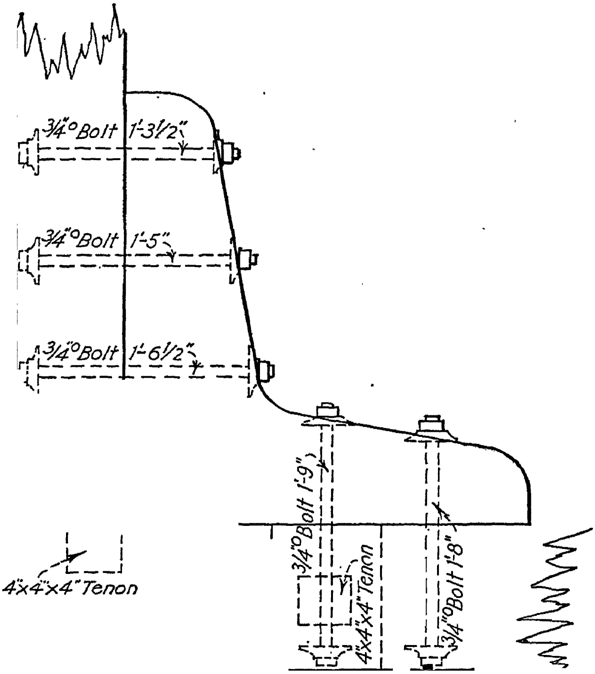


FIG. 70.—Foot of leads.

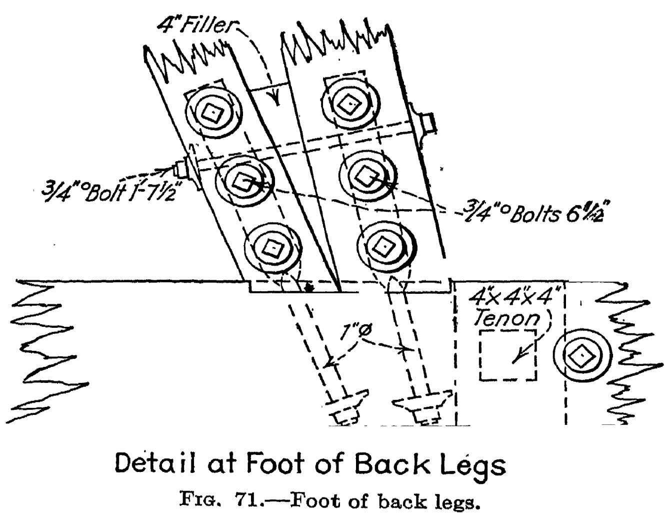


FIG. 71.—Foot of back legs.

larch or tamarack. Hackmatack knees are widely used in shipbuilding.

When transported by truck, the driving outfit will make two or three truck loads. The leads are transported lying lengthwise on the truck and with the lower wide portion of the frame vertical. With pile drivers designed to take piles over 45 feet long, the leads in this position will require such a height of headroom that

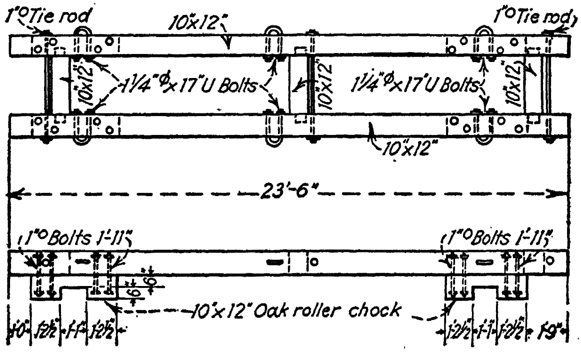


FIG. 72.—Bed frame.

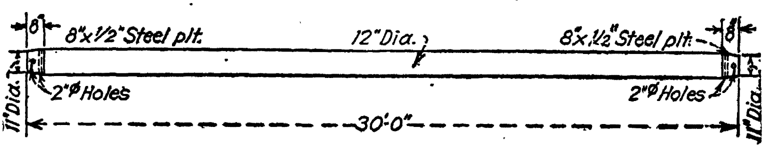


FIG. 73.—Roller.

its transportation through city streets is made difficult. When a pile machine is shipped by rail, the entire outfit can be packed in one gondola car.

Erection.—The pile-driving machine when unloaded should be assembled with the engine and boiler and leads on the same timber bed frame. In erecting the machine, the rollers are first arranged in position on the heavy timbers which later are to support it as it is rolled about from one pile to another. The heavy timber bed frame is then placed upon the rollers in preparation for the mounting of engine, boiler, and leads. The hoisting engine is next placed in its position at the rear of the bed frame. This is usually accomplished by rolling the engine over the end of the frame under its own power.

The leads are then erected in position. They are laid lengthwise on the ground with the bottom end butted against the front end of the bed frame and with the top end elevated slightly. Then they are erected by upending them by means of a tackle fastened to the top end. The power is furnished by the steam engine already on the bed frame. Suitable guy lines should be fastened to the leads to prevent them from overturning sidewise while they are being erected.

After the pile-driving machine has been assembled and is ready to drive piles, the machine is rolled forward on timbers until the leads are in position over one of the stakes marking the positions of the piles. The chain on the end of the pile rope is then carried out to one of the piles and made fast to the butt end of it. The pile is then drawn in toward the machine and hoisted to the top of the leads and placed in them. The drop hammer, up until now supported on a timber chock placed across the leads near the top, is raised, the chock is removed, and the hammer is allowed to fall striking a light blow. The blow is repeated, the pile sinking further into the ground with each blow and the fall of the hammer increasing each time until the pile is driven. A drop of about 15 feet is usually considered sufficient.

In the early part of the driving, the pile is held in position in the leads by a rope sling passed around the pile and held by a man stationed midway in the height of the leads. Later, when the pile is about half driven, the pile is maintained plumb in the leads by "clubs" held by two men stationed on the ground. The clubs are small hardwood saplings and are passed between the pile and the leads. They are held so as to press as a lever against the side of the pile. When the pile has been driven to grade, the hammer is raised and placed again on the chock. The machine is then moved into position to drive the next pile.

The machine can be moved forward or backward by turning the wooden rollers on which the bed frame rests. Iron bars are inserted in holes near the ends of the rollers and men, working the bars simultaneously, cause the rollers to roll. It is at times difficult to roll the machine in this manner, and greater speed may be attained by fastening a line to an anchorage somewhere ahead and using the power of the steam engine to assist in the rolling.

The pile driver can be moved to one side by sliding it sidewise on the rollers. Hooks on the end of ropes are hooked over the

iron bands on the end of each roller. The ropes are made to pass over a suitable arrangement of sheaves to the engine which furnishes the power to slide the machine. The rollers are kept well covered with grease so that the machine will slide readily. It is much easier and quicker to slide the pile-driving machine sidewise than it is to roll it forward or backward. The direction in which the machine is routed over the work should be decided with this in mind.

Jetting Piles.—Where the driving is hard, a water jet may be used to facilitate the driving. In fine sand, piles may be sunk

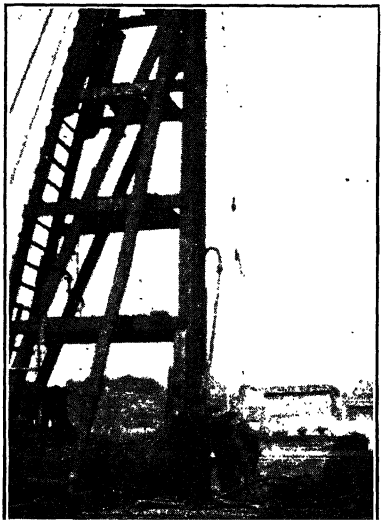


FIG. 74.

entirely with a jet, no drop hammer being necessary. In the usual run of heavier work, however, where the pile is to be sunk its entire depth in the soil it will be found convenient and economical to use a pile-driving machine with a drop hammer together with the jet, as it is necessary to have a weight on the top of the pile to overcome the tendency to float (see Fig. 74).

A pile-driving jet in its simplest form consists of a length of steel pipe connected to a water hose which in turn is connected to a supply of water having a certain number of pounds pressure. The end of the steel pipe should be drawn down to a point so that the force of the stream of water from the jet will be concentrated. The efficiency of the jet will depend to a great extent

upon the water pressure, which should preferably be not less than 40 to 50 pounds to the square inch.

A water jet for use with a pile-driving machine should consist of extra-heavy steel tubing of which the internal diameter is about 1¼ inches; it should be 30 or 40 feet long (see Fig. 74). It should be drawn down at the operating end to about ¾ inch diameter. The upper end should be connected to a heavy hose. The jet may be operated at ordinary city water pressure but it will work more efficiently if connected to a pump. The pump should be large enough and powerful enough to furnish about 300 gallons per minute at a pressure of 150 pounds. A reciprocating pump is suitable for this service.

It is not necessary to adhere to any diameter of pipe for a jet. If the pipe is overlarge, there will be large quantities of water to be drained away or possibly pumped, and considerable sand will be washed up. A good jet for light work can be made of ordinary 1½-inch pipe reduced to 1¼-inch pipe in the middle of its length. The top portion of the jet may be bent to a curve as shown in Fig. 74, or the same result can be attained by the use of two pipe elbows and nipples. A fire hose is generally employed to connect the jet with the source of the water supply. Suitable provision has to be made for connecting pipe threads and hose threads by connecting nipples, unless the hose is equipped with pipe thread connections.

When a pile is to be jetted down without the use of a hammer, the jet is forced downward into the sand at the location to be occupied by the pile until a hole is worn into which the pile can be dropped. In digging the hole, the jet should be moved up and down and worked with a circular motion in the sand until a satisfactory hole has been formed to take the pile. The jet is then removed and the pile is dropped in the hole. Usually, it is necessary to do additional work with the jet. It is forced down along the pile to the foot of it, the pile being rocked back and forth at the same time. This is continued until the pile has been sunk to the desired depth.

An oak pile is heavy and consequently easier to jet than a spruce or yellow pine pile. The jetting or sinking of a pile is largely a matter of flotation. The pile may be regarded as floating upright in a hole filled with water. Any object placed in water will sink until it displaces a volume of water equal in weight to the object immersed. To sink a pile its entire depth by jetting,

it is necessary to place a weight on the top of the pile. When jetting piles without the aid of a pile-driving machine, it is cus-

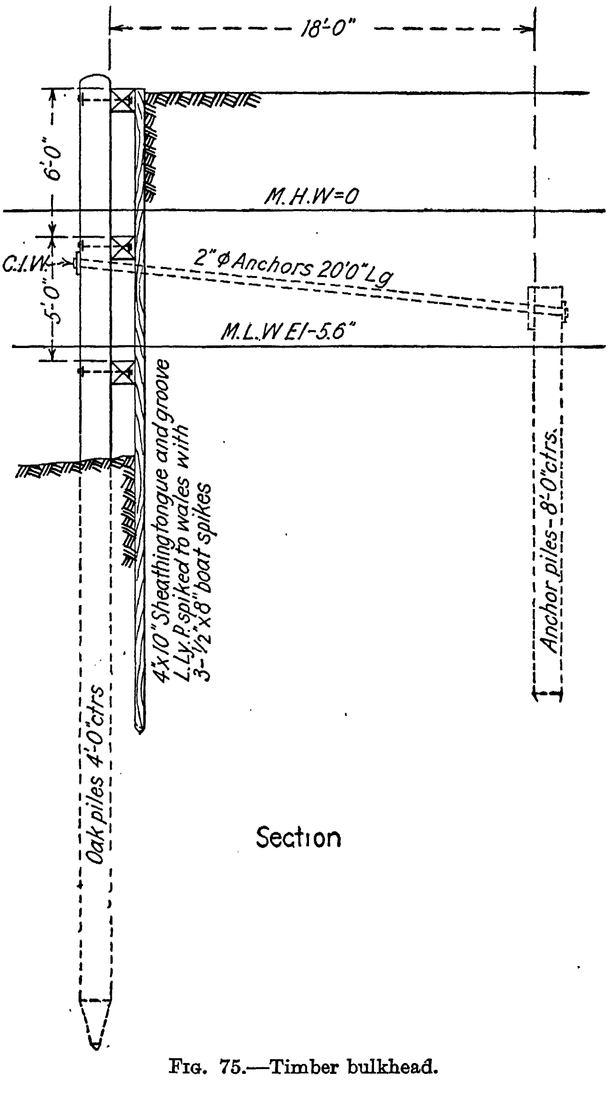


FIG. 75.—Timber bulkhead.

tomary to have one or two men stand on top of the pile. This will seldom be sufficient to sink the pile all the way down and additional weight must be applied. The sinking of a pile will be

greatly assisted if the pile is twisted with a cant hook. Short piles are easier to sink than long ones, as the flotation is less. If the weight is taken off, the pile will immediately rise. To hold it down in place, sand or earth should be shoveled around it to fill the hole and displace the water.

Piles sunk with a jet alone will usually have a vacant pocket below the foot, and subsequently the pile can be made to settle a few inches if struck with a heavy maul. If piles are intended to support the load of a foundation, they should always be driven the last foot or two of depth.

When a jet is used in conjunction with a pile-driving machine, the jet is hung from the top of the pile leads. While the pile is suspended in the leads, a hole is dug with the jet until a satisfactory depth has been reached. The jet is then withdrawn and the pile is dropped in the hole in its place. The pile is then driven with the drop hammer. When the driving becomes difficult, the jet is forced down again along the pile. The jet may be forced down just beyond the tip of the pile to soften the driving or may be worked down only part way, assisting the driving by the lubricating effect of the water flowing upward along the pile.

A considerable quantity of water is employed in jetting piles, and adequate provision should be made to drain the water away from the vicinity of the work. This may prove to be inconvenient and costly, particularly when driving piles in an excavated area. During the jetting, large volumes of soil will be washed up out of the pile holes and will raise the general level of the ground 1 or 2 feet. This soil may be dug out and carted away or may be permitted to remain as may be thought advisable.

Bulkhead.—The construction of a typical timber bulkhead is shown in Fig. 75. The bulkhead shown is of simple design. It will be noted that the anchor piles are cut off at half tide. Anchor rods are 2 inches in diameter to resist deterioration from rusting. Irons should not project far enough from the face of the bulkhead to damage the hull of a boat. Piles driven behind the bulkhead should be provided so that boats can be tied to them.

CHAPTER IV

CONCRETE CONSTRUCTION

Concrete.—Concrete has largely superseded all other materials in the construction of important foundations. Concrete is an artificial stone made by mixing cement, water, sand, and stone in such proportions as has been proved by experience to be best suited to the purposes for which the concrete is to be used. Generally speaking, the quantity of stone required is about equal to the volume of space to be filled with concrete. The quantity of sand required is about that which will fill the voids between the stones and form a solid mass. The quantity of cement required is that which will fill the voids between the particles of sand and cover the surface of both the sand and the stone with a cementing film which will bind all the ingredients together. The amount of water necessary is frequently determined by adding it while mixing the other materials until the mixture is of a consistency which would cause it to flow if placed on an inclined surface.

Cement, when mixed with water, gradually changes its chemical character by absorbing the water in a process of chemical crystallization. It becomes hard and cements together any particles with which it is mixed. Considerable heat is given out in the process.

This chemical change, while it starts almost immediately upon adding the water to the cement, becomes noticeably active at ordinary temperatures in about 1 hour, and develops in that time what is known as an "initial set." The process of setting is retarded somewhat by cold weather, probably due to the dissipation of the heat required for the chemical process. The hardening process continues for several months, the concrete growing stronger with the lapse of time. Ordinarily, concrete will be in a condition which may be called hard, in 2 or 3 days after being mixed, depending a great deal upon the temperature and the degree of hardness signified by the term "hard."

To shape the concrete into the form of the foundations, wooden molds or forms are necessary into which the wet concrete may be

poured. These are so fashioned as to confine the plastic concrete until it has hardened. The forms should not be removed until the concrete is able to stand by itself and until it has attained strength enough to resist ordinary forces which might overturn or break it. In constructing concrete foundation walls, the forms will have to be constructed in advance of the concrete mixing and, unfortunately, the expense of their construction is a considerable portion of the cost of concrete walls.

Concrete Forms.—For most concrete work, forms constructed entirely of wood are the most suitable, particularly in building work where the material in the forms can be used for other purposes in the construction of the building itself after the forms have been removed and taken apart. To make sure of this salvage value being in the forms, it is common practice to construct them of the same materials as will be used in building itself. In fact the boards ordered for the underflooring, roof, or wall sheeting in a wooden-frame building are regularly used for the form boards. The studding ordered for partitions is used for form studs. If rangers are used in the construction of the forms, they may be reused in the building as studding or as scaffold supports.

When deciding upon the proper design of forms for a concrete foundation, the desirability of saving money in the amount of form work and the manner of constructing it presents itself. In some soils a considerable saving in the amount of form work may be affected by allowing the sides of the excavation to serve in place of forms. In some structures, also, the same form lumber may be reused several times in different portions of the work.

Concrete forms may be either built in place, that is individual studs and boards may be erected and nailed together in their final positions, or the forms may be built in sections in advance, these sections later being erected as units.

It is by far the better practice to build forms in place, as they can be built in less time and there will be much less cutting and fitting of lumber. Also, less supervision and planning by foreman and superintendent are necessary as the workmen can see what they are building. When foundation wall forms are to be built in place, it is necessary to wait until the excavation work has been completed to subgrade before the carpenters can be started on the form work. For this reason, where concrete foundations have to be built, it is advantageous to push the excavation for one portion of the structure to completion in advance of

the remainder so that the form building may start as soon as possible.

When it is necessary to save time, it is often desirable for the carpenters to work on the concrete forms while the excavation is in progress, in order to utilize the period, which elapses during excavation, in preparing for the concrete work that is to follow. In such cases, the forms may be built in sections 8 to 16 feet long and placed in piles ready for erection when the excavation

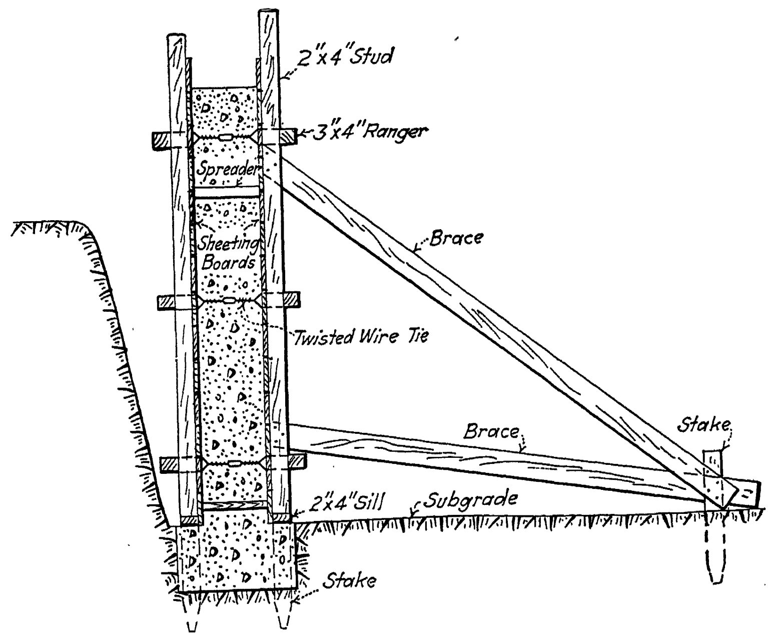


FIG. 76.—Concrete form with rangers.

has been carried down to subgrade. When it is possible to reuse the same form lumber in several portions of a foundation, forms made in sections will prove convenient and time saving. When a saving of time is the only object, it is doubtful whether it pays to build forms in sections in all cases as time can usually be gained by putting a few extra men at work.

Where the forms have to be built under conditions which permit very little working space or where the men have to stand in soft mud to erect them, it will pay to build the forms in a convenient place in sections and erect them as units.

Form Construction.—Two methods of building concrete wall forms are shown in Figs. 76 and 77. A cross-section through a wall form constructed with rangers on opposite sides of the wall wired together to support the studs against the bursting pressure of the wet concrete is shown in Fig. 76. Figure 77 shows a wall form without rangers, the studs themselves being wired in pairs.

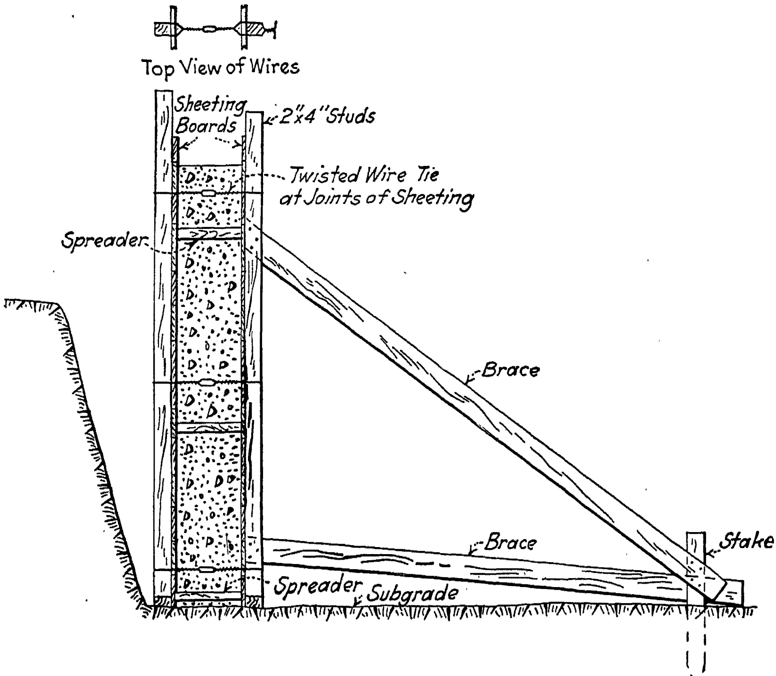


FIG. 77.—Concrete form, studs tied in pairs.

A form without rangers is the cheapest one to construct. It is well suited for building light walls, as wires can be inserted in the cracks between boards. This permits the wires to be placed at the same time with the boards. The wires can be quickly placed around the studs and are accessible for twisting. When thick wire is used, it is customary to notch the boards slightly to admit the wire.

Rangers should always be used if it is important to have a perfectly straight wall, free from undulations and true to line along its length, and if it is not necessary to be parsimonious in the use of lumber.

Rangers provide a convenient method of wiring the studs together against the bursting pressure, as the studs may be placed at random and the wire ties are less frequent than when the studs are wired. The rangers are useful also in binding the forms into a monolithic structure so that fewer braces are necessary to resist displacement. Also, any breaks or weaknesses in the forms are held in check by the rangers. The rangers should be wired at intervals of about 3 or 4 feet, the wires being passed through holes bored through the form boards for the purpose. When rangers are not used and the studs are wired, as in Fig. 77 the studs will have to be spaced opposite each other so that they may be wired in pairs, the wires being spaced 3 feet apart vertically on each stud.

Sheeting.—Narrow ⅞-inch boards, 6 to 8 inches wide, are preferable for form sheeting, as they are cheaper and have less tendency to warp than wide boards. All boards used for concrete work should be surfaced at least on one side, and the smooth side should be turned toward the concrete. All surfaced boards are of one thickness and will give a smooth surface to the concrete. Rough unplaned lumber should be used only where the surface of the concrete will not be visible in the completed structure.

Square-edged boards, surfaced on one side, may be used as likewise tongued-and-grooved boards or shiplap. Yellow pine "12-foot roofers," as they are called, which are always tongued and grooved and surfaced on both sides, are cheap and suitable. Square-edged boards are cheap and the most desirable to use, as in tight places boards can be removed readily to give access for wiring the rangers, insertion of concrete, and the like. The straight joint between the boards chokes up instantly with sand and cement when the forms are being filled so that no leakage occurs and a perfect surface is secured.

Tongued-and-grooved boards are not so easily removed and when forms made of them are dismantled, they become split and broken. In dismantling forms made with square-edged boards, very few boards are broken. Matched boards, however, are preferable for building forms in sections when the sections will be moved several times, as the matched stock holds together well. Almost any good sound board, however, will answer the purpose. Yellow pine, fir, or spruce boards are commonly used. Most other woods are either too expensive for the pur-

pose or are too hard to work. White pine, hemlock, or cypress is often used when procurable in the cheaper grades or when the work is in the neighborhood in which such wood is plentiful. Planks may be used for form sheeting but they are expensive and should be used only in heavy work. Form boards should be nailed to the studs with six-penny nails. While eight-penny nails are the proper size for nailing ⅞-inch boards in ordinary work, the smaller nails are sufficient to hold the boards in place, are easier to drive, and will permit the forms to be dismantled with much less labor.

Studs.—Form studs are generally made of 2-by-4 yellow pine, fir, or spruce. As the studs show the strain of the concrete pressure more than any other part of the forms, only studs of good sound lumber should be used. Most studding carried in stock in lumber yards is surfaced on one edge to bring the studs all to one width. This is necessary if they are to be used with rangers. Almost all small yellow-pine lumber, however, sent from the south is surfaced an all four sides to save freight charges.

The spacing of form studs is an important part of form building. Standard good practice is to space them 2 feet on centers. The strength of a ⅞-inch board and its resistance to bending controls the distance allowable between studs. No deflection will be noticed between studs in concrete forms when the studs are placed 2 feet from center to center. This spacing is good for forms up to 6 feet high, closer spacing being necessary for higher forms. When the spacing is increased to 2½ feet, a deflection upon close inspection may be noticed in wall forms 6 feet high.

While a 2-foot spacing may be termed standard practice, it is by no means universal. A closer spacing is sometimes used and frequently a wider spacing is employed. Concrete forms for ordinary foundation walls are commonly built around the entire area before the placing of concrete is commenced. The concreting when started progresses around the walls, the operation consuming several days before the forms are filled. Each day's work fills the forms to a depth of only 2 or 3 feet. This depth of concrete does not put a very severe pressure on the forms and in such cases the studs may be spaced 30 inches on centers. The author has seen forms built with studs spaced 42 inches apart and the resulting wall had a surface of fair appearance. In this case, however, not over a depth of 1 foot of concrete was deposited at one time and the concrete was mixed to a dry consistency.

In building concrete engineering structures and high walls, it is often necessary to fill the forms rapidly with concrete, frequently filling a set of forms in 1 day. Such a depth of wet concrete puts a tremendous pressure which often amounts to 600 pounds per square foot, on the forms. The studs, rangers, and wire ties should be given a closer spacing in proportion to the rate at which forms are filled. A spacing of 22 inches is reasonable for studs in forms 8 feet high, likewise a spacing of 20 inches for a height of 10 feet.

Other practical considerations that may be taken into account in fixing the stud spacing are that the 2-foot spacing conforms to standard lengths of form boards. The 30-inch spacing has the advantage that greater room is left between studs for the dumping of wheelbarrows.

It is seldom necessary to saw the form studs to a uniform height. Frequently, to save waste, the studs are placed in random lengths and are allowed to project above the boards just as they happen to come. Later, occasional studs may be cut where necessary, as for the dumping of wheelbarrows or other purposes.

Rangers.—The rangers are usually 3-by-4 scantling of the same material as the studs. They should be straight and free from twists and preferably 16 feet in length or longer. To hold the rangers in place previous to wiring them, they may be placed against the studs and nailed temporarily in position. Previous to placing a ranger in position, several pieces of board should be nailed to the studs to form a shelf and support for the rangers, as shown in Fig. 79. These cleats are of great assistance in the erection and wiring of the rangers and are useful as a safety measure, as the carpenters frequently stand on the rangers when building the forms. The ends of the rangers should be butted and the joint should be spliced with pieces of board about 3 feet long so as to form a continuous support horizontally along the form.

The strain which will be thrown upon the rangers will depend upon their spacing vertically on the form, and upon the distance between the wire ties. The top ranger should be placed against the studs with the top about 1 foot below the top of the concrete so as to leave space for the ledger boards or carriers which are to support the runways, if the filling of the forms is done by wheelbarrows (Fig. 83).

The bottom ranger should be placed well toward the bottom of the studs, about 1 foot up from the foot of the studs being a good

position. The intermediate rangers, preferably, should not be spaced over $3\frac{1}{2}$ feet apart; a 3-foot spacing being about right for most work, where a considerable depth of concrete is poured in a day. Forms 10 feet high should have rangers spaced 30 inches near the bottom.

Wiring.—Soft "black annealed-iron" wire should be used for wiring concrete forms since it is necessary for it to withstand severe twisting strains without breaking or snapping in two. Figures 78 and 79 show a good method to employ in wiring

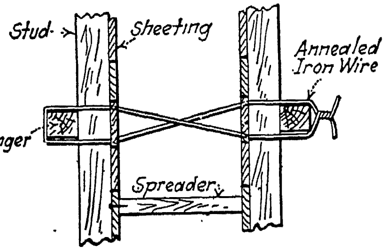


FIG. 78.—Wire ties before twisting.

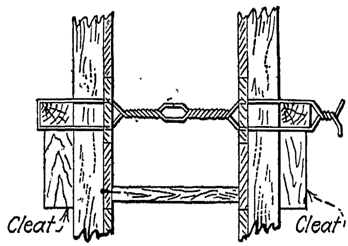


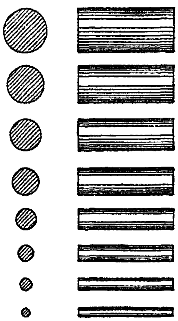
FIG. 79.—Wire ties after twisting.

rangers. Number 8 wire is best for this work and while on light forms this size wire may appear heavier than necessary, it possesses the advantage that it twists up rapidly and is not so liable to break when twisted as wire of smaller diameter. It is not so likely to cut into the wood as a smaller wire. Sizes and weights of annealed-iron wire are given in Table 2; odd gages are omitted from the table. After the rangers have been tacked in position, a piece of wire, cut to the proper length, is passed through the holes which have been bored in the forms, and is crossed back upon itself; the ends are twisted together around one of the ranges, as shown in Fig. 78. A small bar of iron or a stick is then inserted between the two parts of the wire where they cross and the wire is twisted tight in the manner of a Spanish windlass or twister (Fig. 79).

Before threading the wires through the holes, spreaders, which are usually narrow pieces of $\frac{7}{8}$-inch board cut to the proper length, are inserted between the two sides of the form to insure the required space for the concrete. The holes bored for the wires should be $\frac{3}{8}$ or $\frac{1}{2}$ inch in diameter so that the wires may be passed through them easily. This size hole will choke readily with wet concrete and as smooth a finished surface will be

obtained as with a smaller hole. If there is not sufficient space for a man to work inside the form conveniently, the bottom rangers should be placed and wired before the nailing of the

TABLE 2.—SIZE AND WEIGHT OF ANNEALED-IRON WIRE[1]

Full size of plain wire	American Steel & Wire Co's. gage number	Diameter, inches	Feet to the pound	Area, square inches	Breaking strength, pounds	Safe load, pounds
		0.225		0.040	2500	625
		0.192	10	0.028	1800	450
	8	0.162	14	0.020	1300	325
	10	0.135	20	0.013	900	225
	12	0.105	33	0.008	600	150
	14	0.080	58	0.005	350	88
	16	0.062	96	0.003	220	55
	18	0.047	166	0.002	130	32

[1] Iron wire is shipped in standard bundles of 100 pounds.

sheeting is carried much above that level, as otherwise it may be difficult to pass the wires through the holes or to twist them. The wires should be spaced not over 3 feet along the rangers, remembering that with quick pouring the pressure per square foot of form may be as high as 600 pounds.

For tying studs together in pairs, wire of smaller diameter, Nos. 10 and 12 being good sizes, may be used. Figure 77 shows details of this method of wiring forms. In this case, if square-edged boards are used for sheeting the forms, the wires may be placed in the joints between the boards as the latter are placed or, if tongued-and-grooved boards are used, a saw cut through the tongue on either side of the studs will admit the wires. The wires should be cut to length in advance and, as the side of the form toward the bank or outside of the excavation is boarded up, the wires are looped around the studs on that side and the boards are nailed on, the ends of each wire being brought around the opposite studs and twisted securely together.

The wiring of concrete forms should be done with care and should always be inspected for possible defects. It should be borne in mind that the wires take care of all pressure tending to burst the forms outward, the braces merely holding the form from being overturned bodily or pushed out of line.

Bracing.—When concrete forms are wired, the braces may consist of boards nailed to the studs at one end and to stakes driven in the ground at the other. The braces should be spaced about 8 feet apart along the form with rangers, or 5 or 6 feet apart when no rangers are used. If the braces are made of 2-by-4 material, they may be spiked to the studs or butted against the rangers. Where the ground is too soft to give firm support to one stake, a second stake may be driven tandem with it and the two may be then connected by a board, as shown in Fig. 80. Ordinarily, forms are braced only on one side, though they may be braced on both sides if either height or other conditions seem to require it.

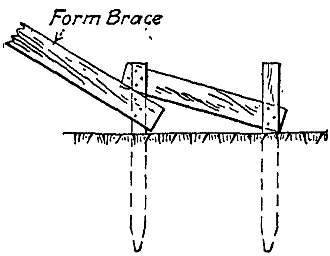


FIG. 80.—Tandem stakes in soft ground.

Where the bank of an excavation is made to serve as the form for one side of a wall, the forms cannot be wired. The braces will have to take the full pressure of the concrete. In this case, either rangers will be necessary or every stud must be braced.

In Fig. 81, a good system of bracing is shown. A vertical timber of suitable cross-section is placed against the rangers with the lower end embedded in the ground and secured by blocking. The braces are butted against this timber at their upper ends, the lower ends butting against pieces of plank set in the ground.

Runways for Wheelbarrows.—When concrete is to be transported and deposited by wheelbarrows, runways for the latter may be built which will be supported partly by the forms. The runways may be supported in the manner indicated in either Fig. 82 or Fig. 83.

To permit the contents of the wheelbarrows to be dumped conveniently into the forms, this runway should be neither too high nor too low. A good position is obtained by placing the runway so that the top of the platform is about level with the top of the form sheeting. It will be seen by referring to the figure,

that the top ranger should be kept at least 1 foot below the top of the concrete to provide room for the ledger or carrier.

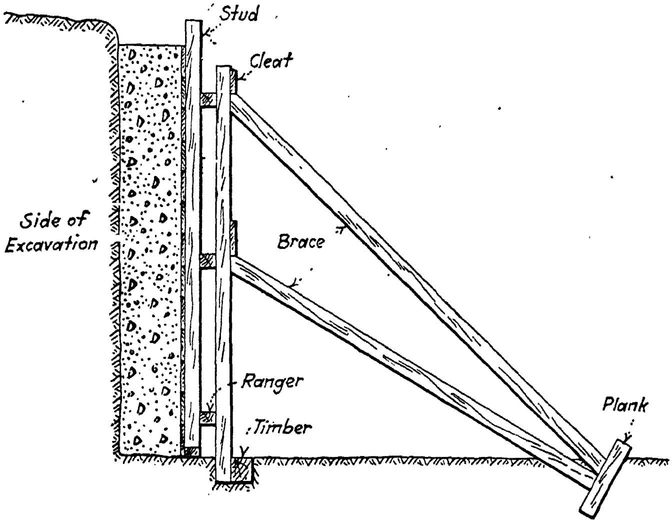


FIG. 81.—Concrete form braced without wire ties.

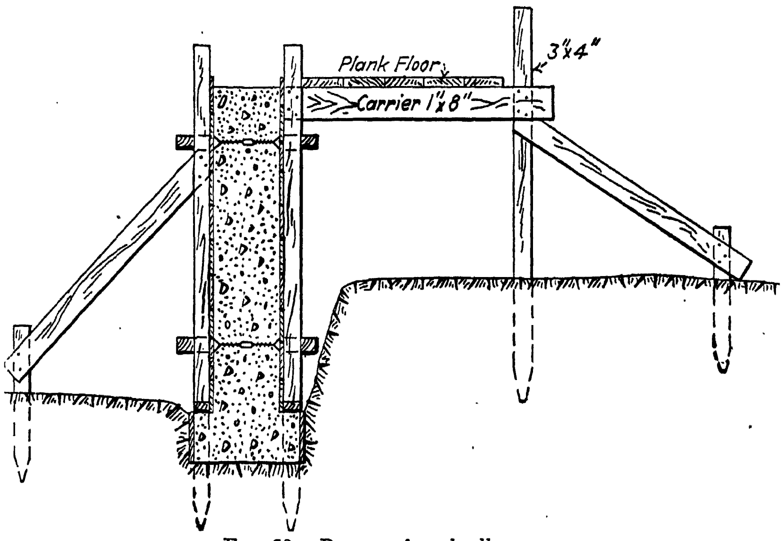


FIG. 82.—Runway for wheelbarrows.

The runway should be constructed with ample width so that the men wheeling the barrows may have room to pass each other.

This requires a width equal to about five 10-inch planks. The supports for the runway may be spaced about 8 feet apart and should always be securely braced.

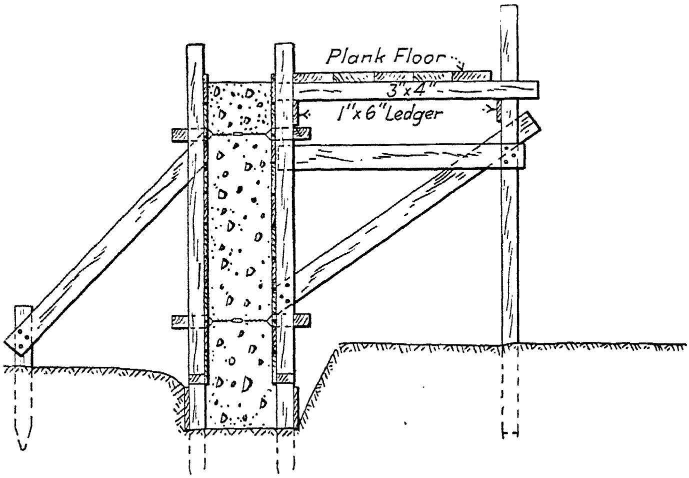


FIG. 83.—Runway for wheelbarrows.

Miscellaneous Form Details.—The boarding of concrete forms should be carried a few inches above the location of the top of the concrete. The position of the top of the wall may be marked by nails driven into the sheeting about 5 feet apart or by a strip of ⅞-inch board nailed to the form. The forms are filled with concrete up to these points, as shown in Fig. 84. The strip of wood is, perhaps, the more accurate method, as the nails are often hard to find by the time concreting has progressed up to them. The former method, however, is generally used.

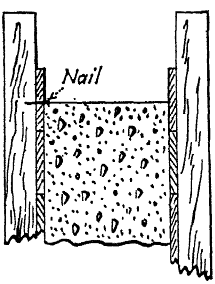


FIG. 84.—Method of marking top of concrete.

It is the practice of some form builders to carry the sheeting of the wall forms exactly to the top of the concrete, ripping the top boards exactly to the line of the top of the wall. This method, however, is wasteful of labor and materials and has little to recommend it, except in building machine foundations or in building retaining walls where the front sheeting, if finished to line, will aid in obtaining a true edge to the top of the wall.

In Fig. 76, the base of a wall having an offset footing is shown. Where the earth is firm, the method shown is an excellent way of supporting the forms. The earth is dug to the exact size of the footing and short 2-by-4 stakes are driven into the ground until their tops are at the proper grade to receive the sill pieces which are also 2 by 4. The stakes are driven into the ground to a line about 4 feet apart. It is necessary usually to start a hole for them with a crowbar, after which they may be driven to exact grade with a sledge. The sills are nailed fast to the tops of the stakes and it is an easy matter then to erect the studs. In some soils, to preserve the shape of the footing it may be necessary to place ⅞-inch boards against the stakes, as in Fig. 82.

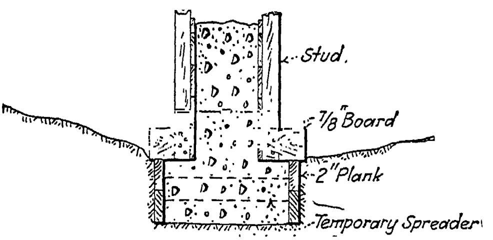


Fig. 85.—Support for form in unstable soil.

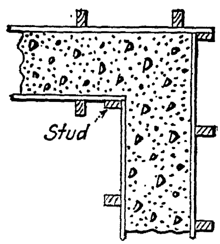


Fig. 86.—Plan of corner detail.

All the material is salvable except the stakes which are allowed to remain embedded in the footing. While this is a good method of forming the wall in one piece, the general practice is to build the footing first and then to erect the wall forms on the concrete footing.

Where the earth is unstable or where it would be objectionable to have the stakes embedded in the concrete, the forms may be supported, as shown in Fig. 85. In this case, the shape of the footing is retained by planks set on edge and held upright by spreaders between them and by stakes driven outside of the planks. To support the forms, pieces of board are nailed to the lower ends of the studs so as to project and rest on the tops of the planks.

Figure 77 shows the details of a form for a wall which has been designed with a plain rectangular base. First, the two sills are laid on the ground, leveled, and held in position by several small stakes. Then the studs are erected on these sills as a base. The studs, in Fig. 77, may be capped with 2 by 4's running longitud-

inally. Such caps are useful in aligning the studs and are a great help in making the braces effective. In a way, they act as rangers and fewer braces are required. If it is not desirable to trim the tops of the studs to length so as to cap them, a line of 2-by-4 studding may be nailed to the faces of the studs instead, or all longitudinals may be omitted entirely.

In the Figs. 86 to 92, inclusive, several details are shown which are commonly met with in concrete work. In Fig. 75, the stud on the inside corner as well as boards to which it is attached will have to be kept back ⅞ inch from the concrete to allow for the boards on the surface of the other wall. This is a detail which

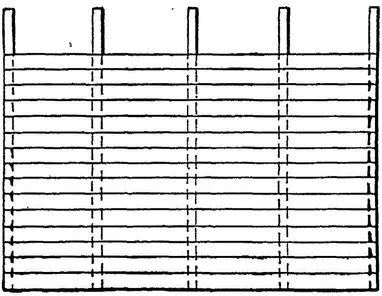


FIG. 87.—Section of form for erection as a unit.

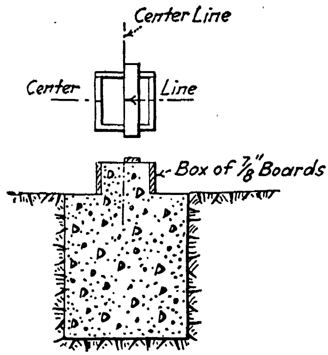


FIG. 88.—Small column pier excavated to size.

has to be arranged for when building forms in sections in advance of their erection. Figure 87 shows a typical form section. It will be noted that each form section has a stud flush with the ends of the boards. This brings two studs together where two sections join. The two studs should be cleated together across the backs.

Figures 88 to 91, inclusive, show several varieties of forms for column footings. In Fig. 88, the hole is dug to the size of the footing and filled with concrete to the surface of the ground. The box form is placed upon the fresh concrete without any bracing and is then filled with concrete. The tops of all column-footing forms should have the center lines marked on the top edges and also have a strip of wood nailed to the top of the form along one of the lines, as shown in Fig. 88. If the other center line is marked across the top of this strip of wood it will be found a

great help in setting the form to line and grade. Figure 89 is similar to Fig. 88.

A method is shown in Fig. 90 of setting a form and holding it firmly in place for filling with concrete where the excavation has been dug oversize. Details of a form are shown in Fig. 91 for a column footing, where the form has to be given several offsets. It may consist of two or more concentric boxes. The lowermost board of the upper box is extended to form a support.

Figure 92 shows a good method of setting anchor bolts for steel columns or for machinery. A template made from a piece of board or a 2 by 4 of suitable length is marked with center lines, and holes are bored with the proper spacing for the anchor bolts. To allow for slight adjustments in the positions of the bolts if

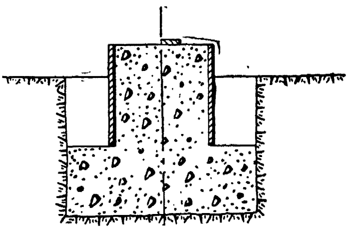


FIG. 89.—Column footing.

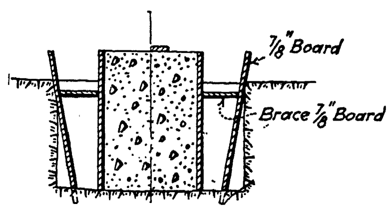


FIG. 90.—Column footing.

necessary, after the concerte has hardened, pipe sleeves are provided into which the bolts are inserted before they are bolted to the template. The pipe should be large enough in diameter to provide a space of about ½ inch on all sides of the bolt. This space is packed solidly with oakum to keep the pipe centered around the bolt and prevent the concrete from entering. The pipe should be tied fast against the template board with string or wire. A piece of galvanized-iron leader pipe 3 inches in diameter serves admirably for an anchor-bolt sleeve. Water should be prevented from entering anchor bolt sleeves in freezing weather. If water fills the sleeves and freezes, enough pressure will be developed to split an ordinary foundation pier.

When the concrete has set, the template may be removed and the oakum should be drawn from inside the pipe, leaving a space around the bolt which will permit small adjustments of position to be easily made. This space finally should be filled with cement grout. Care should be taken to have the bolts project far enough above the top of the concrete to pass through the metal

of the column base or machine bed, allow space for the nut, and leave at least ½ inch besides.

The anchor bolts, shown in Fig. 92, are made of common machine bolts with cut-steel washers to provide a larger grip on the concrete. A better type of anchor bolt is shown in Fig. 93. It is made without a head but attains a powerful hold in the con-

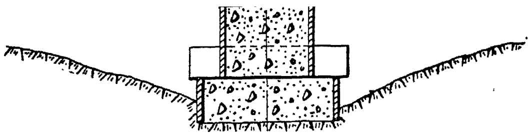


FIG. 91.—Form for offset column piers.

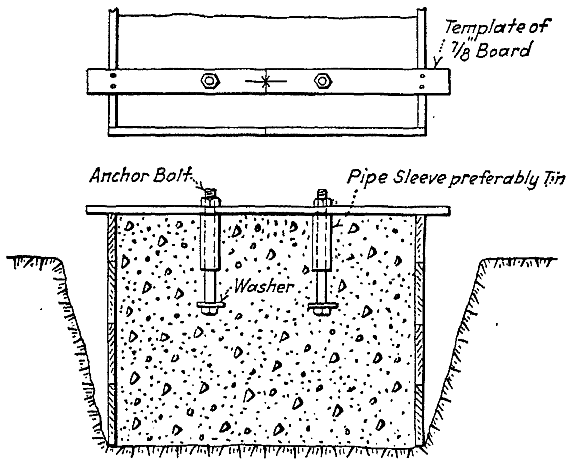


FIG. 92.—Template with anchor bolts.

crete by means of the hook portion of the bolt which is bent at right angles.

In setting anchor-bolt templates, some difficulty will be experienced in setting the template to line, if center lines only are marked on the template and top of the form. The center line on the template should be marked a fixed distance from one edge of it, as indicated in Fig. 94. The template can then be set correctly by placing this edge on marks on the top of the form located an equal distance from the center line. It is usual practice to nail the templates to the forms after the latter have been completely erected and made ready to receive concrete.

It might be well to mention here that it is customary to keep the top of the concrete in a column footing or a machine founda-

tion about 1 inch below the elevation shown on the plans. This 1-inch "grouting space," as it is called, is retained so that the column or machine may be set on wedges at the correct height, and adjusted to a level position. The space between the column or machine base and the top of the concrete should be filled finally with a cement grout or a rich mortar.

Joints.—All cement work contracts more or less in setting. The contraction in concrete walls and other structures causes fine cracks to develop at quite regular intervals extending all the way through the walls. In large heavy masses of concrete, contraction cracks will occur at intervals of about 30 feet. Con-

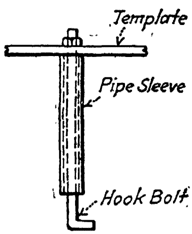


FIG. 93.—Anchor bolt.

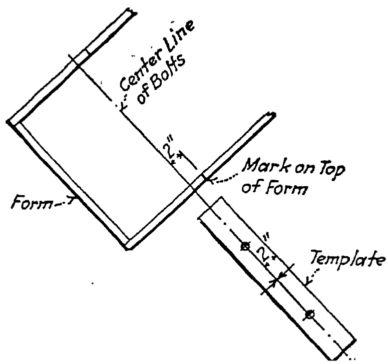


FIG. 94.—Method of setting templates.

crete walls 1 to 2 feet thick will usually show them about 15 feet apart.

The tendency to shrink increases in direct proportion to the quantity of cement in the concrete. A rich mixture shrinks more than a lean mixture. A concrete wall, which has been made of a very lean mixture and which has been built by filling only about 1 foot in depth of concrete in the form each day, will frequently require close inspection to reveal the cracks. This is probably due to the small quantity of cement causing contraction and to the fact that the portion of concrete deposited in the form each day has completed the greater part of its contraction by the time the next depth of concrete is placed. Concrete walls, which are built by filling an entire section of form at one pouring with concrete of the usual proportions, will usually develop cracks in 2 or 3 weeks.

Contraction cracks may be prevented by a plentiful quantity of reinforcing bars embedded in the concrete or the contraction may be controlled by causing the parting of the concrete to take place at joints especially provided at intervals for the purpose. When it is required that a wall should be built by filling the entire height of a form in one pouring of concrete, it will usually be found

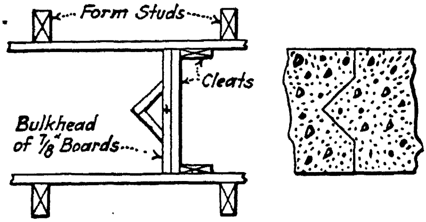


FIG. 95.—Plan of bulkhead for "V" joint.

impractical to build the entire length of wall, if it is a long one, in one piece. In such a case, it is customary to divide the wall by vertical bulkheads into sections equal to a day's work. The design of the joints should be such that the adjacent portions of the wall are united structurally and such that the usual contraction may occur at the joints without affecting the rest of the wall.

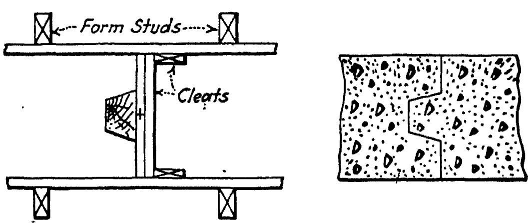


FIG. 96.—Plan of bulkhead with form for joint.

The forms should be divided into sections by vertical bulkheads, as shown in Figs. 95 and 96. The form for the tongue of the joint should be turned toward the portion of wall which will be built first, so that a groove will be formed in the end of that portion of the wall. When the concrete has set sufficiently, the bulkhead and the tongue form are removed and the adjacent portion of the wall is concreted. The simple V-shaped joint (Fig. 95) is the preferable one of the two. The joint, shown in Fig. 96, while very popular at one time, has fallen into disfavor because it has been found that the concrete during the process of

setting will adhere along the surface of the joint and, when the wall shrinks, the tongue of the joint cracks across the base of the beveled concrete tongue. It is necessary, also, to be very careful in removing the tongue form so that the concrete will not be broken along the joint. Covering the old concrete along the surface of the joint, shown in Fig. 96, with heavy oil, asphaltum, and similar substances before placing the new concrete only serves to make the occurrence of cracking somewhat less frequent. The plain V-shaped joint (Fig. 95) with a wide bevel is far less liable to bind and the form for this type is much easier to remove without danger of breaking the concrete. For these reasons, it is the better style of joint to use. A water-tight joint may be formed

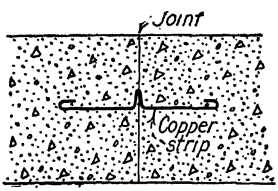


FIG. 97.—Water-tight joint.

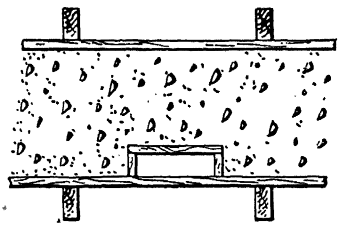


FIG. 98.—Joint for concrete and brick walls.

by inserting a strip of copper in the concrete, as shown in Fig. 97. The copper should be a continuous strip with all joints soldered with a lock joint. The metal should be crimped V shaped at the center so that there will be excess material to draw out as the concrete contracts. The two sides of the crimped part of the strip can be lightly soldered together to prevent the entrance of concrete into the crimped portion.

Where a brick and a concrete wall intersect at right angles to each other, provision for joining the two walls should be made by attaching a three-sided box to the inside of the concrete wall form (Fig. 98) in such a way as to leave a recess in the concrete which will be at least 2 inches, preferably 4 inches, deep into which the end of the brick wall may be built later.

Openings.—Openings must usually be provided in concrete foundation walls for windows and doors. These may be formed by inserting a frame in the wall forms of ⅞-inch boards the width of the wall (see Fig. 99). Care must be taken that the frame is truly rectangular and that it is set perfectly plumb inside the form. The frame should be made to the exact size

of the opening called for and braced properly so that it will not become distorted by the pressure of the concrete.

A nailing strip of 2-by-3 or 2-by-4 lumber should be tacked lightly to each vertical side of the frame and beveled in such a manner that it will remain embedded in the concrete when the forms are removed, as indicated in Fig. 99. The nailing strips embedded in the concrete furnish a means by which the windows and doors may be secured to the walls. Unless the plans call for

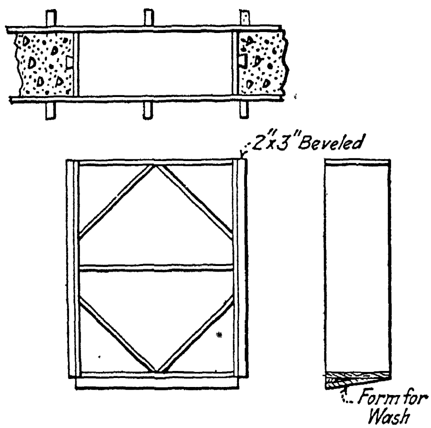


FIG. 99.—Form for window opening.

another position, the nailing strips should be placed in the center of the walls and should extend the entire height of the opening.

Generally, the forms for the window openings must be made so as to mold a slope or wash to the bottom of the opening.

FORMS FOR CONCRETE FLOORS

The majority of fireproof buildings are designed with concrete floor slabs supported by steel beams and columns. To install the concrete floors, it is necessary to provide forms constructed of standard commercial lumber. The floor may consist of a flat slab of concrete resting on the top flanges of the beams. The beams in this design remain uncovered and exposed. This construction is used in power plants and manufacturing buildings.

Another type of concrete floor consists of a flat slab of concrete supported by steel beams, the concrete of the slab being carried around the sides and bottoms of the steel beams so that the latter are completely encased and fireproofed with the concrete.

Building laws commonly require that all parts of the beams be protected by not less than 2 inches of concrete, if the beam supports a wall, and not less than 1½ inches in any case. Some insurance rules require a covering of 2 inches.

Beams Exposed.—Where steel beams are not to be encased in concrete, the forms are of simple design. Figure 100 shows the

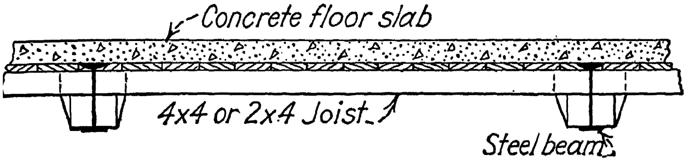


FIG. 100.—Floor form, beams exposed.

usual construction. The boards may be square edged or shiplap. The top surface of the boards should be kept flush with the tops of the beams. The joists may be of 2-by-4, 3-by-4, or 4-by-4 material. They are supported from the bottom flanges of the beams by a piece of material of the same cross-section as the

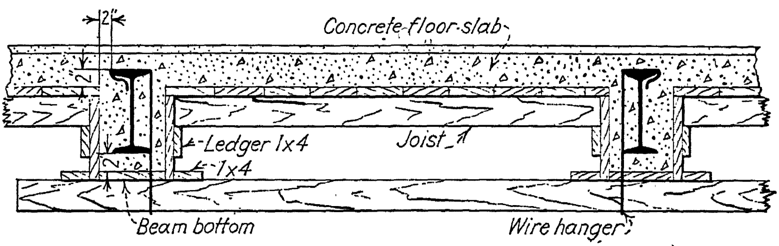


FIG. 101.—Floor form, beams fireproofed.

joist. The blocking is held to the end of the joist by a short piece of board. The joist with blocking attached is usually referred to as a "jack." The jacks should be spaced close enough together to prevent the sheeting boards from bending excessively and so that too great a load will not come upon the jack. Twenty-four inches is about the maximum spacing that is permissible. A spacing of 20 inches is commonly used in forms for a floor slab 4 inches thick. The size of a jack is determined by the span from beam to beam and by the thickness of floor slab and spacing of jacks.

Beams Fireproofed.—Where the steel beams are to be encased in concrete, the forms for the floor slabs are usually made as shown in Fig. 101. The entire form work is suspended from

the top flanges of the beams by steel wires or steel rods. The wires are bent U shaped in the middle of their length to support the lower joist and both ends are bent around the top flange of the beam as shown. Number 8 annealed wire may be used for this work. Rods 3/16 or 1/4 inch in diameter make excellent hangers for forms and possess the advantage of not needing any labor to straighten them out, as is necessary with wire. The

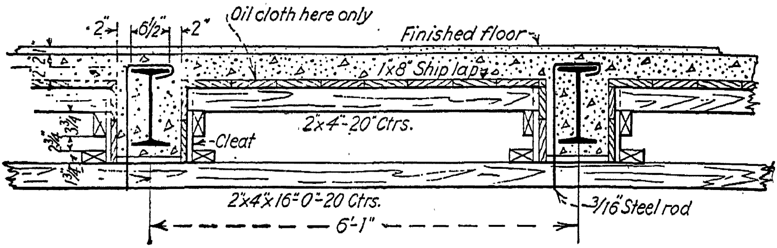


FIG. 102.—Floor form.

strength of hangers made of wire and steel rods is discussed elsewhere in this chapter.

While the illustration shows the construction clearly, there are a few details that should be especially noted. The beam bottoms should be cut inside the beam sides. This is to facilitate the erection and dismantling of the forms. In arranging for the

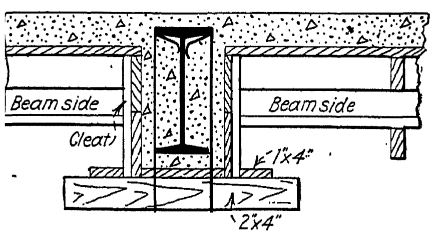


FIG. 103.—Girder-beam form.

building of the forms in the field, it will be found advantageous to standardize the width of all beam bottoms. Usually a few widths will serve for the entire building. The concrete should extend 1½ or 2 inches beyond the tips of the beam flanges but the covering may be made slightly thicker if needed. The building of the forms is greatly simplified by adhering to a few standard widths.

The joists under the beam bottoms need not be continuous. Each joist should be long enough to support the bottoms of two

or three beams and to extend across the spans between them. Other examples of form building are shown in Figs. 102 to 106.

A great saving in the cost of form building can be had by building each side and bottom of the beam box of one board, as

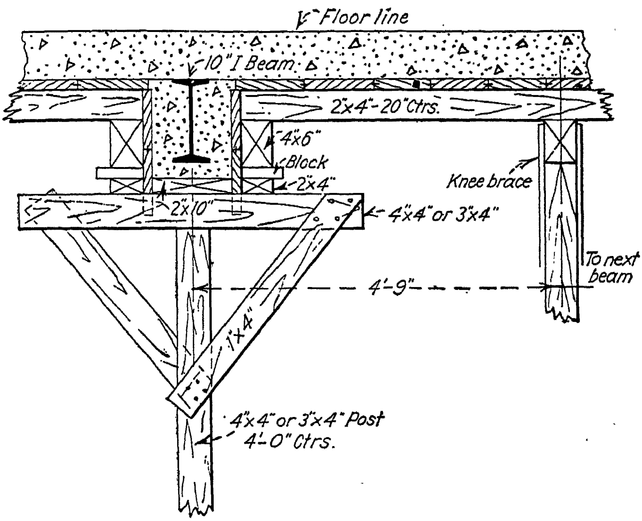


FIG. 104.—Floor form, posted.

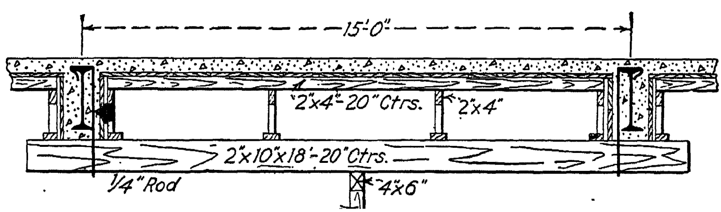


FIG. 105.—Floor form, long span.

shown in Fig. 101. If the steel beams are small, this can be easily done. The width of board for a side is then equal to the depth of the beam. The width of board for the beam bottom is equal to the width of flange plus either 3 or 4 inches, depending on the thickness of fireproofing required. This is a more economical design than forming the box with cleats as shown in the other figures, as the labor of building up the sides and bottoms with cleats is saved.

An electric drill can be employed for drilling the holes for the hangers in the beam bottoms and will both speed up the form building and lower the labor cost.

The forms around a girder beam can be made as shown in Fig. 103. The beam bottom is supported by a short 2-by-4 held to the girder by two wires bent around the flange of the beam. A better method is shown in Fig. 106. The form under a girder does not have to support so much weight as the form under a beam.

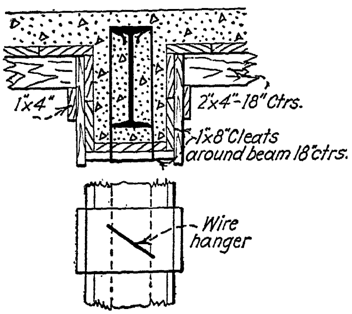


FIG. 106.—Girder beam bottom.

Sizes of Lumber.—Several sizes of lumber can be used in building forms. The simplest construction is obtained by using 1-by-6 lumber throughout for all members. The lumber should be surfaced on one side and both edges. This lumber can be used for joists, ledgers, and form sheeting.

Companies that make a specialty of building forms for concrete floors commonly use only 1-by-6 and 1-by-4 lumber. Contracting companies doing a general class of work will find it more convenient, on small buildings, to use ordinary boards for form sheeting and use 2-by-4 or similar lumber for the form joists.

Spacing of Joists.—The spacing of form joists will depend upon the size of lumber, the thickness of concrete slab, and the distance to be spanned by the joist. The forms should be designed for a fiber stress of 1500 pounds per square inch and by computing the strength based on actual dimensions of the lumber. In small spans, joists may be spaced between 16 and 24 inches center to center, a 20-inch spacing being an average one.

Strength of Lumber.—As a practical check on the strength of lumber derived from theoretical computations, the author made two tests for the strength of a 2-by-4 beam with a span of 6 feet. The pieces tested were fir and measured 1¾ by 3¾ inches in cross-section. The object of making the tests was to determine, in a practical way, what would appear to be the greatest allowable uniformly distributed loading, and also to measure the amount of deflection. The results of the two tests checked consistently and were as shown on page 121.

Loading, pounds	Measured deflection, inches	Computed fiber stress
600	1/8	1320
700	1/4	1540
800	5/16	1750
900	3/8	1975
1000	1/2	2200

It should be noted that the beam held a load of 1000 pounds and did not give way, although it was evidently near the limit of its strength. During the test it became apparent that a load of 700 pounds was as much as could be considered a safe uniformly distributed load for a 2-by-4 joist on a clear span of 6 feet. A fiber stress of 1500 pounds was derived by computation as corresponding to the load of 700 pounds. As this fiber stress appears to check with results experienced with many floor forms in actual construction, it seems suitable for use in computations for the design of concrete forms.

Strength of Wires.—The ultimate and safe loads for an annealed iron wire of various gages is given in Table 2. The safe load for an annealed wire No. 8 gage with a factor of safety of 4 is given as 325 pounds. The strength of a hanger for form work, with the two parts bent over the flange of a steel beam, will be determined by the load necessary to straighten out the hooked portion. To ascertain the strength of wire as used for a form hanger, the author made several tests on a single wire hooked over a beam. The tests were made on No. 8 annealed iron wire. The results may be tabulated as follows;

Pounds	
300	Hook unchanged
332	Hook opened slightly
350	Hook opened more
416	Hook opened more
433	Hook opened more
500	Hook opened more, with slow continuous movement and failure by spreading

It will be noticed that the wire was not broken in the tests but that the hanger failed by spreading of the portion hooked over

the beam. A load of 300 pounds appeared safe for one part of wire or 600 pounds for each hanger.

For greater strength round rods of mild steel should be employed. Tests to ascertain the loads that can be safely supported by iron and steel wire and round steel rods gave results as tabulated below. The values given are for a single wire or rod hooked over the flange of a 12-inch steel beam. In every case the wire or rod failed by spreading of the hook where it was bent around the flange. It will be noted that stiff steel wire when hooked over a beam did not show much more supporting power than annealed wire.

TEST FOR STRENGTH OF FORM HANGERS

Description	Apparent Safe Load, Pounds
Annealed iron wire No. 8 gage	300
Stiff steel wire No. 8 gage	325
Mild steel rod $\frac{3}{16}$ inch diameter	350
Mild steel rod $\frac{1}{4}$ inch diameter	550

Oilcloth.—Where ceilings are to be painted and no plaster is to be applied, the form marks left on the surface of the ceilings by the boards may be objectionable. The presence of form marks can be prevented by covering the deck sheeting with "old-fashioned" oilcloth, laid with the pattern side up. The surface to come in contact with the concrete should be painted when in place, with oil. If this is not done, the oilcloth will stick to the concrete and will be difficult to remove. It is not practical to apply oilcloth to the sides and bottoms of the beams. An acceptable finish can be obtained by the use of square-edged boards.

Removal of Forms.—Concrete forms should not be removed too soon after being filled; sufficient time should be allowed to elapse for the concrete to harden. If they are removed when the concrete is still soft, the latter will adhere to the boards in spots and leave a pitted surface. Concrete in the process of setting will shrink away from a form and a slight crack will appear between them. As the setting progresses, this crack becomes more clearly defined until the boards are completely separated from the surface of the concrete. At about this time also, the concrete

will have become hard enough to cause a bar of iron to ring when tapped on the concrete.

When the forms appear to have loosened, it will usually be safe to remove them. In warm weather, they can usually be removed on the second day following the concreting; in colder weather, more time will be required. Forms under floors should be left in place until the concrete has hardened to a very light color. This will usually require 10 days to 2 weeks.

It is not necessary to apply grease or oil to the inside surface of concrete forms to prevent their sticking to the concrete, as the latter will always draw away clean from the forms if given time to set properly without the aid of any greasy substance applied to the boards. Grease or oil applied to the surface of the forms, also, is very likely to discolor the surface of the concrete.

CONCRETE MATERIALS

Cement.—Cement is manufactured by burning and fusing together suitable mixtures of limestone and clay and pulverizing the resultant clinker to a fine powder. The cement usually is of a standard and well-known brand, the merit of which has been proved by years of satisfactory use and whose quality seldom requires any minute inspection.

Prices of cement are quoted by the barrel but it is customary to ship in either paper or cloth bags. The paper bags are supplanting the cloth ones in favor. Cement can also be bought in bulk and shipped loose. A bag of cement contains 1 cubic foot. A quotation for cement should specify how the cement is packed. The cost of bags is always included in the price quoted. Cloth bags are returnable with an allowance of 10 to 15 cents for each bag. Paper bags cannot be returned, as they are broken when opened.

Considerable saving in price may be affected when sufficient cement is required, by buying in carload lots. The minimum quantity constituting a carload lot is 173 barrels, or 692 bags. Cement, even in carload lots, should always be purchased through local dealers, as they are able by arrangement with manufacturers to furnish it at the lowest prices obtainable while, at the same time advantage is taken of the dealers' storage and unloading facilities.

Sand.—Sand usually requires some inspection. It may be too fine or it may contain loam. The sand may be roughly tested

by rubbing a quantity of it in the palm of the hand. If it seems to rub away to nothing, it is probably too fine to use for concrete. If it contains loam, it will soil the hand. When water is added to a concrete batch made with fine sand, the latter will flatten into a silty mud and result in a stony batch. Sand will seldom prove too coarse for making concrete, but it is very likely to be too fine.

The best test for sand is to shake up a small quantity of it in a glass jar or bottle with a quantity of water and then allow the contents to settle. Loam and the finer grains will be deposited in the top layer of the contents and the coarser grains will be deposited at the bottom, thus giving an exhibition of its quality. The proportion of dirty loam or clay is readily determined in this manner. Grains that will pass through a screen having a ¼-inch mesh are usually classified as sand. Grains which are retained on the screen are classified as gravel. Sand may be regarded as too fine when over 30 per cent passes through a screen having a No. 40 mesh.

Broken Stone and Gravel.—Whether the stone aggregate of the concrete should be crushed stone or gravel must be decided upon, although usually either will be acceptable. Broken stone makes a slightly stronger concrete than gravel. Where the construction requires careful work and where strength rather than mass is a feature as in thin reinforced walls and floors, broken stone is to be preferred to gravel. For massive work, gravel is equally desirable. Gravel is usually somewhat cheaper than crushed stone; a gravel concrete is easier to shovel, flows more readily in chutes, and is easier to spade and manipulate in the forms.

As a gradual grading of sizes is always obtainable with gravel, it possesses on that account another very practical advantage over broken stone. Concrete made of an aggregate of a uniform size is not as dense or as strong as that made of an aggregate whose particles are graded from the smaller to the larger sizes. The smaller particles fill the interstices between the larger particles and thus decrease the percentage of voids and the amount of mortar necessary to fill them.

The percentage of voids in gravel with the sand screened out is about 35 per cent; the percentage of voids in broken stone with the dust screened out is about 45 per cent; the percentage of voids in broken stone screened to one size and with the dust out is about 55 per cent. It will be seen from the foregoing that only

about three-quarters of the quantity of mortar is necessary to fill the voids in a fixed amount of gravel as is necessary to fill the voids in the same amount of broken stone. The comparison between gravel and stone screened to a size is even more marked. A saving in the quantity of mortar means a saving in sand and cement and consequently a saving in cost per yard of concrete.

Crushed rock containing stones graded from the smallest sizes to the largest, and known as the run of the crusher, is preferable to stone which has been screened to one size. Stone dust present in the stone is not harmful unless present in large quantities. Stone that will not pass through a ring 2½ inches in diameter is generally assumed to be too large for use in a concrete batch. Broken stone or gravel consisting of stones which are graded from ¼ to 2½ inches in diameter will make the best concrete for heavy construction. For light walls and floors and reinforced concrete not over 12 inches thick, the size of the stones should not exceed 1 inch in diameter.

Before placing purchasing orders for sand, gravel, and stone, it is well to visit the pit or quarry to see what quality of materials will be furnished. The greater part of the sand in a bank may be too fine or there may be a scarcity of gravel. A material man may offer to furnish 1000 cubic yards of gravel in a week and a visit to the pit may disclose that to furnish that amount would require a very much longer allowance of time.

In obtaining quotations of prices on stone and gravel, there may be some confusion in comparing prices by the cubic yard with prices by the ton. In making such comparisons, it is customary to deduct one-fifth from the price per cubic yard to obtain the corresponding price per ton. A yard of broken stone is assumed usually to be 2500 pounds. Gravel weighs 100 pounds to the cubic foot, crushed stone 95 pounds, and sand 90 pounds, for material which is clean and dry.

Concrete Proportions.—The relative proportions of cement, sand, and stone which should be employed in mixing concrete for different classes of construction are about as follows:

Foundations and massive structures	1–3–6
Strong and impervious structures	1–3–5
Reinforced concrete and thin walls	1–2–4
Structures requiring extra strength	1–1½–3
Cinder concrete for filling	1–2–5

An inspection of the table below will show that, in ordering materials for concrete, the quantity of stone needed will be about equal to the total yardage of concrete and the quantity of sand

TABLE 3.—QUANTITIES FOR ONE CUBIC YARD OF CONCRETE

Proportions by volume			Ratio	Quantities of materials		
Cement	Sand	Stone	Mortar to stone	Cement, barrels	Sand, cubic yards	Stone, cubic yards
1	1½	3	0.61	2	0.42	0.85
1	2	4	0.55	1.6	0.45	0.90
1	3	5	0.60	1.2	0.52	0.86
1	3	6	0.50	1.1	0.46	0.93
1	4	8	0.48	0.85	0.48	0.96

about equal to one-half the quantity of stone. In proportioning one bag of cement equals one cubic foot.

CONCRETING METHODS

Concreting Methods.—In planning the concrete work, the operation of construction should be arranged so that there will always be work for each class of labor to perform. There should always be excavation or concrete work for the laborers and form work for the carpenters. By dividing the construction of the structure into several sections which may be constructed successively, all classes of labor can be kept constantly employed. The excavation should be carried well ahead so that the concrete forms can be built. The form work should be kept in advance sufficiently to permit the concreting to progress at all times. The form work is more likely to lag behind than the excavation or the concrete mixing, and for this reason, particular attention should always be paid to keeping the progress on the forms up to schedule.

By proportioning the number of men working at each class of work properly, the rate of progress in each branch of the construction can be controlled nicely. A one-bag mixer will usually require a gang of 12 to 16 men for concreting. When not engaged in concrete work, this gang may be employed in excavating or other general labor work.

The methods to be followed in building a concrete foundation will depend a great deal on the quantity of concrete to be placed and the type of foundation to be built. Selection of methods will be influenced also by the general contour and slope of the site of the work, as well as the general distribution of the concrete; *i.e.*, by whether or not a great proportion of it is to be deposited in one spot, as in a heavy pier, or in column footings for a building where the concrete is distributed over a large area.

Usually conditions will designate at once whether the concrete should be mixed by hand or by machine. If a large quantity of concrete is to be mixed, a machine mixer should be employed. There is an appreciable saving in money per yard of concrete in mixing by machine over mixing by hand, and the machine is a great convenience as well. The quality of machine-mixed concrete, also, is much more dependable than that mixed by hand. On small jobs, the possession of a concrete machine will often decide the matter in favor of machine mixing even though the quantity of concrete is small.

The most important question to decide very often is the manner in which the mixed concrete is to be placed in its final position. This may be accomplished, ordinarily, either by shoveling it into place, conveying it through chutes, or wheeling it in barrows or buggies. Less frequently, it may be transported in cars running on rails, in buckets handled by derricks, or conveyed through chutes operated from elevating towers. Many of the details connected with the other arrangements of the concreting plant will depend a great deal upon the methods selected for handling the mixed concrete.

The simplest case of handling mixed concrete is met with in pavement or floor work, where the concrete may be prepared by hand on a mixing platform and shoveled from the platform to place. In this work, the platform may be moved as the work progresses so that the mixed concrete may be always shoveled to place and need not be loaded into wheelbarrows and transported. When machine mixers are used for this work, it is best to station the mixer at one spot and convey the concrete in wheelbarrows or concrete buggies to the place of deposit. Considerable time is required to move the ordinary concrete mixer from one place to another and, if the machine were to be moved several times in a day, much time would be lost. For this reason, it usually will not prove practical to chute the concrete to place from the mixer.

Where foundations are to be constructed of concrete entirely below ground level or, at most, projecting only 1 or 2 feet above the surface, the concrete may be chuted directly from the mixer into the forms. The chutes may be made of boards suitably braced (Fig. 107) or of sheet iron in sections, similar to the ordinary coal chutes, with sides about 6 inches high and about 18 inches wide. Usually, the forms will have to be divided into sections by bulkheads.

This method of handling the mixed concrete is much more economical and speedier than any other way, provided only one or two men are needed to attend the chute. When more men

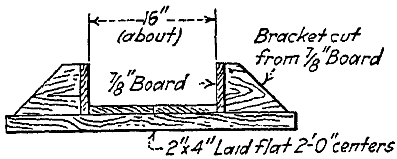


FIG. 107.—Cross-section of concrete chute.

are needed, they may be just as profitably employed in wheeling the concrete. With the larger sizes of mixing machines, more men may be used on the chute with economy than with the smaller machines. If elaborate runways are not needed, the comparative efficiency of wheeling in barrows to chuting the concrete is a simple case of balancing the number of men which will be necessary to wheel the output of the machine against the number necessary to attend the chute. Runways can often be simply constructed by laying a few planks on the ground. The cost of constructing a runway supported by posts will often equal the cost of mixing and placing per cubic yard of concrete, and it is evident that the manner in which the mixed concrete is to be transported should be given careful consideration.

Building foundations which extend over a considerable area and consist of light walls and scattered column footings are usually built by wheeling the concrete in barrows. The process of filling the wall forms will usually cover a period of several days, the concrete being deposited in layers 2 or 3 feet deep working progressively around the entire length of the walls until the forms are filled or else the walls are divided vertically into sections each of which constitute a day's work.

The column footings, as a rule, will be about level with the subgrade and may be easily reached by simple runways of 2-inch

plank laid on the ground. The walls, however, will usually extend above the surface of the ground and more elaborate runways may have to be constructed (see Fig. 109). Concrete buggies, which hold two to three times as much concrete as wheelbarrows, may be employed for conveying the concrete and provide an economical method of transporting it, but naturally they cannot be rolled easily up steep inclines. The runways for them, also, need to be stoutly built.

In building foundation walls by wheeling the concrete in barrows, the mixer should be stationed in one position and as it need not be a portable machine, it may be of large size. The runways should be arranged to lead to all parts of the work where concrete is to be deposited and should be planned so that the barrows can return over a different route to the mixer. The barrows used for conveying the mixed concrete are too heavy to handle if filled level full and consequently more barrows and men for wheeling them are needed than are needed for wheeling the unmixed materials. The number of men needed varies according to the distance over which the concrete must be wheeled.

This method of concreting requires considerable lumber for building the runways and their supports and an extra supply of wheelbarrows for transporting the concrete. On the other hand, it is not necessary to bulkhead sections of the form with vertical joints and, as the likelihood of great pressures from wet concrete is less, the forms may be of lighter construction. The expense of moving the mixer frequently is also avoided as well as the delays incident to getting ready for concreting with the mixer in a new position.

As concrete mixers are often hired by a daily or a weekly rate and union rules in some localities compel the hiring of a highly paid union engineer for the operation of either a steam- or a gasoline-driven machine, it is economy to arrange the form work so that once the mixer is started, it can be operated continuously until the placing of the concrete is completed.

Location of Mixer.—When the mixed concrete is to be chuted into place, the mixer should be placed in such a position as to reach all parts of the area with the least number of men working on the chute. It should be placed as close as possible to the area requiring the greatest volume of concrete so as to be able to place the greatest amount of concrete with the shortest possible chute, as this will require the least number of men.

The mixer should preferably rest upon the ground, if it is possible to chute the concrete from that elevation, or if the top of the concrete is to project above the ground a few feet, it may be necessary to elevate the mixer on cribbing or blocking of some kind so that it will be high enough to chute into the top of the form. It takes considerable time to elevate a mixer several feet from the ground, and it will seldom pay to attempt raising any machine heavier than a one-bag portable mixer.

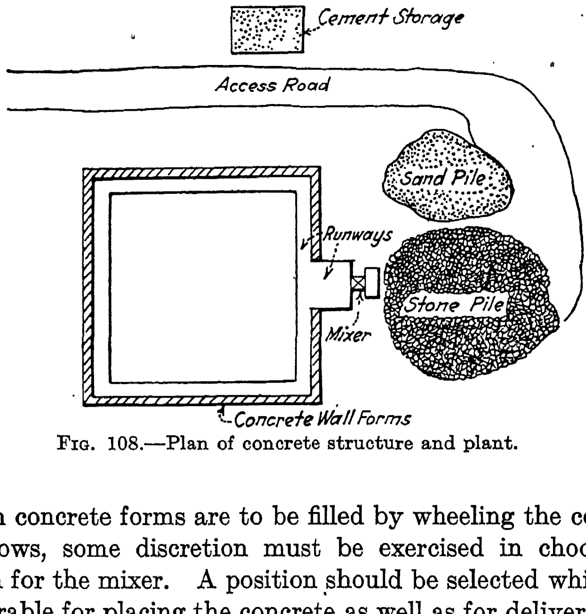


FIG. 108.—Plan of concrete structure and plant.

When concrete forms are to be filled by wheeling the concrete in barrows, some discretion must be exercised in choosing a position for the mixer. A position should be selected which will be favorable for placing the concrete as well as for delivering the unmixed materials. The mixer should first of all be stationed close to a suitable place for the storage of sand and stone, so that an ample supply of materials may be always kept on hand and so that the serving of the materials to the mixer may be cheaply and conveniently done (see Fig. 108). The location selected should preferably be central to all parts of the work, so that none of the concrete will need to be wheeled to long distances.

It is preferable that the mixer be placed on high ground as near as possible to the level of the top of the forms so as to give a level run for the wheelbarrows transporting the wet concrete (see Fig. 109). If it is not possible to arrange this, inclined runs must be built to the top of the forms or the mixer can be elevated

so that both the unmixed materials, as well as the mixed concrete, can be wheeled on inclined runways.

Proportioning the Batch.—The proportions of cement, sand, and stone to be employed in mixing the concrete is always specified in either the plans or the specifications for the work and these proportions must be adhered to, but the size of the batches mixed each time is controlled by the capacity of the mixer. The manufacturers of concrete mixers rate the size of the machines in capacities according to the cubic feet of concrete which the drum

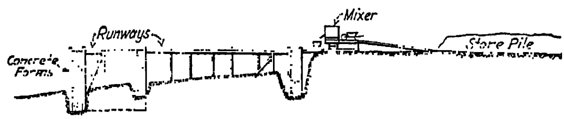


FIG. 109.—Section through concrete structure and plant.

of the machine will mix properly. Among the men actually working with the machines they are often designated as a one- or two-bag mixer, or larger, according to the number of bags of cement in the maximum batch which the machine will mix. This, however, is not a very definite way of rating capacities as a mixer which is large enough to handle a two-bag batch of 1-2-4 proportions may be too small to handle a two-bag batch of 1-3-6 concrete. The mixers commonly used on work of ordinary size are either of one- or two-bag capacity.

The quantities of sand and stone going into a concrete batch may be regulated by the use of measuring hoppers made for the purpose or, as is widely customary, they may be measured in the wheelbarrows in which the sand and stone is delivered from the storage piles to the mixer. The concrete barrows which are best to use for this purpose have a capacity of 3 cubic feet when heaping full and 2 cubic feet when level full.

The basis of all measurements of quantities in proportioning the materials for a concrete batch is the contents of a bag of cement. This is approximately equal to 1 cubic foot. The capacities of the barrows should be tested by dumping two or three cement bagfuls of sand into them and noting the relation of the surface of the sand to the top of the barrow.

When a one-bag mixer is used to mix a concrete batch of 1-3-6 proportions and the barrows used have the capacity mentioned

above, the batch will consist of one bag of cement, one barrow of sand, and two barrows of stone or, to elucidate more clearly:

1 bag of cement........................equals 1 cubic foot
1 barrow of sand heaping full...........equals 3 cubic feet
2 barrows of stone heaping full.........equals 6 cubic feet

For proportioning a batch of 1-2-4 proportions with the same equipment, the batch is measured as follows:

1 bag of cement........................equals 1 cubic foot
1 barrow of sand level full.............equals 2 cubic feet
2 barrows of stone level full............equals 4 cubic feet

If the machine is a two-bag mixer these quantities may be doubled by employing twice as many barrows. Batches of any other proportions may be mixed by using multiples of whole or half bags.

As stated in Chap. I, the size of a concrete mixer is based on the quantity of 1-3-6 concrete that a machine will mix in one batch. To gain a large output when mixing concrete of 1-2-4 proportions with a 1-bag mixer, the batch should contain 1½ bags of cement, 3 cubic feet of sand, and 6 cubic feet of stone. Each batch will then give a quantity equal to a batch of 1-3-6 proportions. Each barrow is then loaded heaping full and a low cost for mixing and placing is obtained.

As the quantity of stone is twice as large as the quantity of sand used in each batch, and as the stone is much harder to shovel, the stone should be piled close behind the mixer and the sand farther away. This will occasion the smallest possible amount of wheeling for the material forming the bulk of the batch.

The water used in the ordinary type of portable one-or-two-bag mixer is usually led through ¾-inch pipe and a hose, into a measuring tank on the mixer from which it flows into the drum. The quantity of water in a batch should be regulated to bring the batch to the proper consistency. The consistency for most work should be what might be described as "plastic." There should not be so much water added as to cause the mortar to separate from the stones nor should the concrete be so dry as to appear to crumble.

Concrete for sidewalks and floors may be made of the same consistency as for other work but some workmen prefer to mix it rather dry and to pound it when it is in place with iron rammers.

TABLE 4.—QUANTITIES AND PROPORTIONS THAT CAN BE MIXED IN MIXERS

Ingredients	Proportions	No. 5S	No. 7S	No. 14S	No. 21S	No. 28S
Cement	1	1 bag	2 bags	4 bags	6 bags	9 bags
Sand	1½	1½ cu. ft.	3 cu. ft.	6 cu. ft.	9 cu. ft.	13½ cu. ft.
Stone	3	3 cu. ft.	6 cu. ft.	12 cu. ft.	18 cu. ft.	27 cu. ft.
Cement	1	1 bags	1½ bag	4 bags	5½ bags	8 bags
Sand	2	2 cu. ft.	3 cu. ft.	8 cu. ft.	11 cu. ft.	16 cu. ft.
Stone	3	3 cu. ft.	4½ cu. ft.	12 cu. ft.	16½ cu. ft.	24 cu. ft.
Cement	1	1 bag	1½ bags	3½ bags	5 bags	7½ bags
Sand	2	2 cu. ft.	3 cu. ft.	7 cu. ft.	10 cu. ft.	15 cu. ft.
Stone	3½	3½ cu. ft.	5¼ cu. ft.	12¼ cu. ft.	17½ cu. ft.	26¼ cu. ft.
Cement	1	1 bag	1½ bags	3 bags	4½ bags	7 bags
Sand	2	2 cu. ft.	3 cu. ft.	6 cu. ft.	9 cu. ft.	14 cu. ft.
Stone	4	4 cu. ft.	6 cu. ft.	12 cu. ft.	18 cu. ft.	28 cu. ft.
Cement	1	1 bag	1 bag	3 bags	4½ bags	6 bags
Sand	2½	2½ cu. ft.	2½ cu. ft.	7½ cu. ft.	11¼ cu. ft.	15 cu. ft.
Stone	4	4 cu. ft.	4 cu. ft.	12 cu. ft.	18 cu. ft.	24 cu. ft.
Cement	1	1 bag	1 bag	2½ bags	4 bags	6 bags
Sand	2½	2½ cu. ft.	2½ cu. ft.	6¼ cu. ft.	10 cu. ft.	15 cu. ft.
Stone	4½	4½ cu. ft.	4½ cu. ft.	11¼ cu. ft.	18 cu. ft.	26 cu. ft.
Cement	1	½ bag	1 bag	2½ bags	4 bags	6 bags
Sand	2	1 cu. ft.	2 cu. ft.	5 cu. ft.	8 cu. ft.	12 cu. ft.
Stone	5	2½ cu. ft.	5 cu. ft.	12½ cu. ft.	20 cu. ft.	30 cu. ft.
Cement	1	½ bag	1 bag	2½ bags	4 bags	5½ bags
Sand	2½	1¼ cu. ft.	2½ cu. ft.	6¼ cu. ft.	10 cu. ft.	13¾ cu. ft.
Stone	5	2½ cu. ft.	5 cu. ft.	12½ cu. ft.	20 cu. ft.	27½ cu. ft.
Cement	1	½ bag	1 bag	2½ bags	3½ bags	5 bags
Sand	3	1½ cu. ft.	3 cu. ft.	7½ cu. ft.	10½ cu. ft.	15 cu. ft.
Stone	5	2½ cu. ft.	5 cu. ft.	12½ cu. ft.	17½ cu. ft.	25 cu. ft.
Cement	1	½ bag	1 bag	2 bags	3 bags	4½ bags
Sand	3	1½ cu. ft.	3 cu. ft.	6 cu. ft.	9 cu. ft.	13½ cu. ft.
Stone	6	3 cu. ft.	6 cu. ft.	12 cu. ft.	18 cu. ft.	27 cu. ft.
Cement	1	½ bag	½ bag	1½ bags	2½ bags	3½ bags
Sand	4	2 cu. ft.	2 cu. ft.	6 cu. ft.	10 cu. ft.	14 cu. ft.
Stone	8	4 cu. ft.	4 cu. ft.	12 cu. ft.	20 cu. ft.	28 cu ft.
Cement	1	1 bag	1 bag	2½ bags	3½ bags	5 bags
Gravel	5	5 cu. ft.	5 cu. ft.	12½ cu. ft.	17½ cu. ft.	25 cu. ft.
Cement	1	½ bag	1 bag	2½ bags	3½ bags	5 bags
Gravel	6	3 cu. ft.	6 cu. ft.	15 cu. ft.	21 cu. ft.	30 cu. ft.

By using a dry mix of concrete, they are able to apply the finish coat of mortar at once, without waiting several hours for the base concrete to take its initial set. The troweling of the finishing coat can be finished then close upon the placing of the base concrete. This avoids keeping the cement finishers at work several hours after the rest of the men have finished their work for the day. With this method also, the finish coat of mortar is more thoroughly incorporated with the base concrete.

Cinder Concrete.—The concrete floors in fireproof buildings are commonly constructed of cinder concrete. The building code of New York City permits the use of cinder concrete mixed

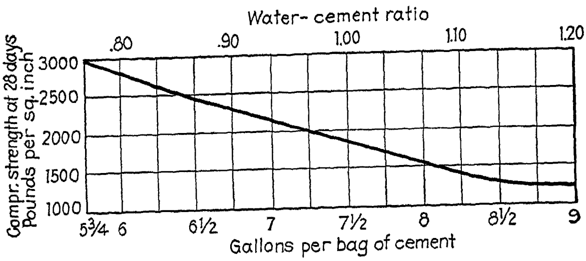


FIG. 110.—Relation of water-cement ratio.

in the proportions of 1 part cement, 2 parts of sand, and 5 parts of hard steam-boiler cinders. A good concrete can be obtained with a 1-3-5 mixture. Cinder concrete is also employed for filling in roof crickets and toilet floors. It can then be mixed in leaner proportions. Cinder concrete is much lighter than stone concrete. It weighs 108 pounds to the cubic foot. Building codes permit a compressive stress of 300 pounds to the square inch when used in floor slabs.

Cinder concrete possesses several characteristics which recommend it for use in building construction. Its lightness permits a saving in steel beams and columns. It can be cheaply mixed and placed. Its strength is ample for floor construction. Nails can be easily driven into cinder concrete and holes for passage of pipes can be quickly cut through it.

There are several varieties of steam cinders, differing in weight, hardness, and color. Only hard steam cinders should be used. Samples of cinders should always be obtained before placing an order with dealers. Steam cinders may be mixed into concrete without screening. Usually there will be some large clinkers in

the pile which can be shoveled to one side and later either broken up or used as back filling.

Water-cement Ratio.—The strength of concrete is determined by the proportions of the mix. A concrete containing a large proportion of cement will develop a greater compressive strength than one containing less cement. The strength of concrete is also determined by the quantity of water mixed with each bag of cement. The relation of the quantity of water to the quantity of cement is known as the water-cement ratio.

The relation of the water-cement ratio to the compressive strength of concrete is given in Table 5 and is represented graphically in Fig. 110. The water-cement ratio is measured by relative volumes. It is computed by dividing the volume of water, expressed in cubic feet, by the volume of cement. The volume in one bag of cement is 1 cubic foot. The water-cement

TABLE 5.—ASSUMED STRENGTH OF CONCRETE MIXTURES

Water-cement ratio, gallons of water per bag of cement	Volume of cement to total of unmixed sand and stone	Approximate compressive strength at 28 days, pounds per square inch	Consistency
8¼	1–7	1400	Plastic
7½	1–6	1800	
6¾	1–5¼	2300	
6	1–4½	2800	
8¼	1–6½	1400	Wet
7½	1–5½	1800	
6¾	1–4¾	2300	
6	1–4	2800	

ratio can also be expressed in gallons of water to each bag of cement. Allowance should always be made for the quantity of moisture originally in the sand and stone.

A dry concrete has a much greater compressive strength than a wet concrete but it is not suitable for use in reinforced concrete work or thin walls.

It should be noted that a concrete mixed with equal volumes of water and cement should have a compressive strength of nearly 2000 pounds per square inch at 28 days.

Slump Test.—Concrete should be mixed as dry as the workability desired will permit. To control the workability of mixed concrete a slump test has been devised. The methods employed have become standardized for this test. A conical receptacle is made of sheet iron and filled with concrete. The cone should measure 4 inches in diameter at the top, 8 inches at the bottom, and should be 12 inches high. The concrete is thoroughly tamped and the cone is immediately removed. The slump or settlement of the concrete should then be measured. Concrete intended for use as reinforced concrete should show a slump of 8 inches or the 12-inch cone should settle to a height of 4 inches. For use in floors and foundations the slump can be as little as 2½ inches.

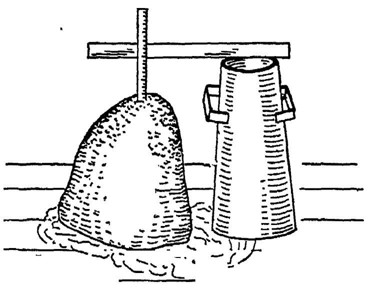


FIG. 111.—A slump test.

Machine Mixing.—The concrete materials may be charged into the mixing machine in any sequence but it will be found best to dump the stone first into the mixer, followed by the sand, and then the cement. The water is added last while the other materials are being revolved about in the drum. When the mixer is equipped with an elevating charging hopper and a water tank, all the dry materials for the batch are dumped into the charging hopper which upon being raised deposits them by gravity into the revolving drum of the mixer. As soon as the batch is admitted to the drum, the water is allowed to run from the tank above the machine and is mixed together with the other materials.

Hand Mixing.—The materials for a concrete batch which is to be mixed by hand, may be added in any order and will result in good concrete if they are sufficiently worked together, but mixing concrete by hand is laborious work and much time and effort may be saved by mixing the materials in a systematic order. The method of mixing may be best illustrated by assuming the batch is to consist of two bags of cement, two barrows of sand and four barrows of stone.

A mixing board measuring about 10 by 12 feet constructed of ⅞-inch boards nailed to 2 by 4's laid flat and spaced about 2 feet apart will be suitable and light enough to be portable. When it is desired to save the cost of a mixing platform, floor joists or other plank may be laid flat on the ground and the mixing may be done on them.

First, the sand and the cement are thoroughly mixed dry. One barrow of sand is dumped on the mixing platform and is spread out flat. The contents of a bag of cement is then spread evenly over the sand. Another barrow of sand and another bag of cement are similarly placed on the pile. By alternating the placing of sand and cement, the operation of mixing is aided. The dry mixture of sand and cement is then mixed thoroughly with shovels until it is of an even color. Usually two turnings will be sufficient for this, one outward from the center of the pile and one backward to the center. The dry mixture is then spread out evenly and the four barrows of stone are spread over it.

Water is then added to the batch and the mass is mixed with the shovels. Four turnings are necessary to mix the stone with the sand, two outward from the pile and two backward.

Filling the Forms.—Before any concrete is deposited in the forms, the entire space inside the forms should be cleared of pieces of wood, loose earth, and other débris. The filling of a form should proceed by dumping the concrete at various points along its length. If the concrete is dumped in one spot, the excess water and cement will flow away from the other materials and result in a pile of solid materials at one place and water at another. As soon as the placing of concrete has begun, one or more men should be stationed inside the form to spread the concrete evenly and to spade it with shovels in such a manner as to break up any nests of stones that may form. The shovels should be shoved down along the inside surface of the forms to force back any stones that may have gathered there in clusters. The stone clusters, if not broken up, will show as honeycomb spots on the surface of the concrete after the forms are removed.

The same results obtained by spading may be gained by any means which will cause the concrete to move about in the forms. Churning and poking the concrete with a pole will give equally as good results if the concrete has been mixed to the proper consistency.

The surface of the concrete in the forms should be kept level, while the forms are being filled, to prevent the water gathering at one end and taking a good part of the cement with it. Leaks in the forms will give the most trouble when an excess of water is present. If the concrete is of a plastic consistency, ordinary cracks between boards and knot holes as large as 1 inch in diameter, will choke quickly with small stones and mortar without causing any blemish on the surface of the concrete. Holes and cracks which are too large to choke quickly may be covered with pieces of board or may be calked tight with oakum or waste. The men doing the spading should remove all the spreaders as the filling progresses up to them.

Joining the Work of Successive Days.—If the operation of filling a form is to be accomplished by concreting on several successive days, some attempt should be made to obtain a close union between the layers of concrete placed on succeeding days. To this end, the last batches put into the form at the end of a day's run should be a great deal drier than usual to absorb any excess water present in the form. If a day's work is finished with several inches of water in the form or with very wet concrete in the top layer, the surface of the concrete on the following day will be covered with a slightly gelatinous layer of sediment ½ inch or more thick. This is composed of *laitance*, fine loam, and cement, with which the succeeding day's work will not knit firmly. A few dry batches at the completion of a day's work will leave the top rough and provide a good surface for the adhesion of fresh concrete.

Large stones may be placed into the top of the concrete at the end of a day's work projecting half way to form a good bond with the next day's work. Short lengths of timber may be similarly embedded in the top of the concrete, and removed the following day, thus providing a tongued-and-grooved joint. If a particularly strong bond is required, the surface of the old concrete should be thoroughly wet with water and the new deposit of concrete should be started with several batches of rich mortar containing no stones. The mortar batches form a cushion for the concrete batches and prevent stones from gathering in nests along the joint with no mortar between them. Mortar batches are expensive and should be spread thinly over the previous day's work.

Concreting in Freezing Weather.—It is often necessary to do concrete work during freezing weather. Many difficulties are experienced from freezing temperatures, both in mixing and placing the concrete and in protecting the work from freezing. While concrete which becomes frozen does not suffer any permanent surface deterioration, its strength is greatly decreased. Troweled surfaces of sidewalks and floors will scale off where frozen.

Fresh concrete when frozen may be readily recognized by its color. When frozen it turns white, whereas ordinarily, concrete will retain its dark slate color in cold weather for several days. Concrete that seems to be frozen can be tested by placing it over a stove or by immersing it in hot water. If frozen it will become soft. If not frozen it will remain unchanged. Concrete that is badly frozen will usually swell and spall in spots.

There are several precautions which may be successfully taken to prevent concrete from becoming frozen. The sand and stone before mixing may be freed from frost by piling them over steam coils or fires, and the mixing water may be heated by allowing steam to bubble up through it from a steam pipe inserted into the water barrel.

When the warm concrete has been deposited inside the forms, the boards furnish a protection to the sides of the walls, and it is only necessary to prevent the radiation of heat from the top surface of the concrete. This may be prevented by a layer of straw packed inside the forms. If the straw is placed directly on the fresh concrete at the completion of a day's work, it will become embedded in the fresh concrete and will be difficult to remove entirely when concreting is resumed on the following day, unless a covering of tar paper or something similar is placed between the concrete and the straw. The forms may be covered with tarpaulins under which steam pipes are installed, filled with steam from a portable boiler. Wood shavings make a good covering for sidewalks and floors. A covering of sand 4 to 6 inches deep will effectually prevent freezing in ordinary cold weather and is a particularly convenient material to use especially in the top of wall forms.

During very cold weather, there is always considerable difficulty experienced with the water-supply pipe and hose freezing solid. As preventive measures, the pipe may be covered with sand or any other available material, or the water pipe may be

kept warm by a steam pipe run parallel to it. Both pipes may be wrapped together in tar paper or cement bags. When not in use as at the end of each day's work, the water pipe and hose supplying water to the mixer should be disjointed, and all water in them should be drained out to avoid freezing during the night.

Repairing Broken Concrete.—The edges and corners of concrete walls and machine foundations are often accidently broken off, and it becomes necessary to repair the injury by restoring the broken part to its original shape. Patches put on by plastering with mortar in the usual way soon loosen and drop off. The following method of making repairs to broken machine foundations in exposed positions has been used successfully. Figure 112 represents a foundation which has been broken along one edge and also indicates the method used in repairing it.

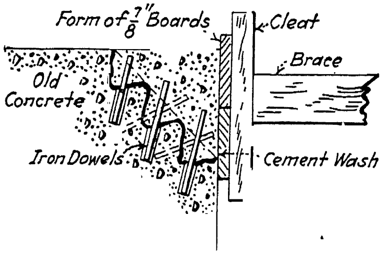


FIG. 112.—Repair of broken concrete foundation.

The broken corner should first be cut out into a series of cup-shaped steps and a number of holes not too far apart and scattered over all parts of the broken area should be drilled in the bottom and sides of the depressions. Pieces of steel bars or dowels are inserted in the holes previously drilled and are carefully set in a cement mortar a day or two in advance of the remainder of the patch. A form is then placed in position to mold the surface of the concrete. The whole broken area should then be soaked thoroughly with water, applying the water several times so that plenty of it is absorbed by the old concrete. The whole area is then painted with a wash of neat cement and water.

The remainder of the space is then filled with concrete. The cement mortar in which the dowels are set, as well as the concrete of which the patch is made, should be mixed in the same proportions as were used in the original concrete. The success experienced in applying a repair to broken concrete depends upon the extent to which excessive shrinkage in the new concrete is avoided as well as upon the tenacity with which the patch adheres. If the patch is made of the same proportions as the original concrete, unequal shrinkage is avoided and the surface

textures of the two concretes will be alike. If the work has been carefully done, the repair will be permanent and the outlines of the patch will be very hard to perceive.

CONCRETE FLOORS

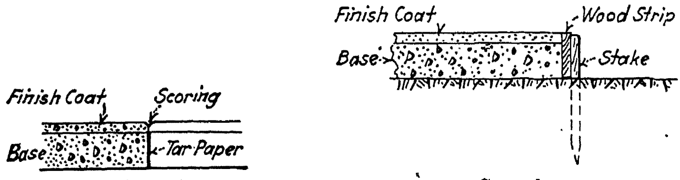
Types of Floors.—The different types of cement floors classify themselves most naturally according to the nature of the top wearing surface and according to the manner in which it is applied. While there are patented finishes incorporating colors and other materials in the aggregate besides cement, the most popular types of concrete floors are those having a plain finish of cement and sand, those having a granolithic finish, or those having a wearing surface containing some variety of floor hardener. Each of the foregoing types of cement floor consists of two layers or portions, the thick base portion of coarse concrete and the thinner, finer-grained portion forming the top wearing surface.

Base.—A concrete floor base may be formed of any of the standard mixtures of concrete. For a strong floor a concrete base mixed in the proportion of one part of cement, two parts of sand, and four parts of stone is preferable. It will usually prove worth while to insert steel reinforcement in all floors whether they are laid directly on the ground or not.

A concrete floor base will shrink upon taking its set and joints should be provided which will permit the contraction to occur at fixed locations. Contraction joints can be arranged by dividing the floor into areas which will coincide with convenient stopping places for each day's work. The concrete placed on different days should be prevented from bonding together by inserting a strip of tar paper in the joint (Fig. 113) or by coating the surface of the older concrete with oil or grease.

When the base concrete is to be poured around reinforcing steel, it should be mixed with enough water to make it flow slowly into all vacant spaces when manipulated with a shovel. Too great a quantity of water in the base course should be avoided, as any excess will work up through the finish mortar and interfere with satisfactory progress in troweling the latter. Initial set usually takes place after concrete has been mixed about 2 hours, and during this period a portion of the excess water disappears. It is well, for this reason, to permit this period of time to elapse before starting to deposit a finish mortar, particularly if the latter is made of a wet mix.

To obtain a level surface and the correct thickness at all points, a suitable system of guides must be provided. An arrangement of screeds is usually installed so that a straightedge worked with a saw-like motion across them will scrape the mortar level with the tops. Where a floor is to be laid on earth or a cinder fill,



Contraction joint. Screed.

FIG. 113.—Floor screed and joint.

the screeds may be constructed as shown in Fig. 113. Floor screeds should preferably be placed about 8 feet apart. The screed may consist of a strip of board or a 2- by 4-inch scantling supported on suitable stakes driven into the subgrade. Where the floor is to be laid on wooden form boards, the screed may be constructed as shown in Fig. 114. The legs supporting this screed should be toenailed to the form. In both cases concrete may be placed on both sides of the screed embedding the supports

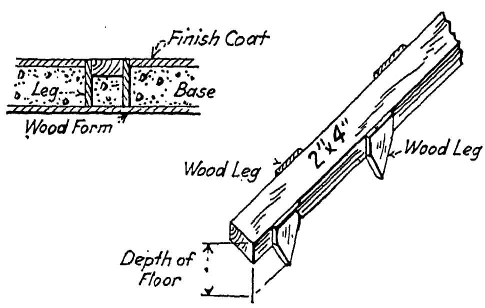


FIG. 114.—Screed.

temporarily in the fresh concrete. Before the concrete has set hard, the screeds should be removed and the holes left by the legs of the screeds should be filled with fresh concrete.

The proportioning and the manipulation of the mortar of the several kinds of finish coats furnish the greater part of the technical problems connected with cement-floor construction and these should now be described.

General.—The methods employed in building a concrete floor may be varied somewhat to suit working conditions. In some

cases it may be desirable to place the finish mortar on the base concrete before the base has had time to set. This type of floor construction is known as a "monolithic floor." It is the style of floor most commonly laid. Under other circumstances, the finish course may be placed on the base concrete several weeks or several months after the base concrete has set hard. This style of floor is often described as "base and topping." This latter method of building a floor is advantageous in power-plant construction as the rough base course furnishes a substantial working floor and by delaying the placing of the surface course until the

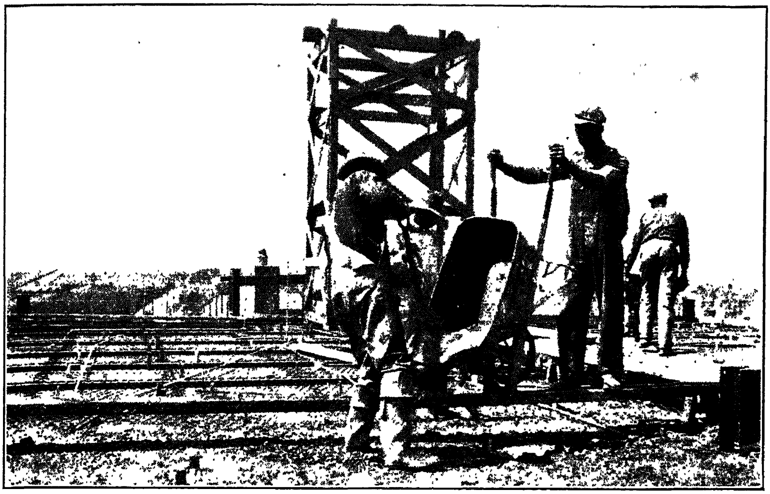


FIG. 115.—Depositing cinder concrete.

completion of the job, the floor escapes all the wear and abrasion incident to construction operations.

Monolithic Floor.—A monolithic floor, as the name implies, is constructed in such a way that the base and the finish courses set together into a one-piece floor. The usual procedure is to place the base concrete and 1 or 2 hours afterward to spread the finish coat over it to a thickness of from ½ to 1 inch. The finish mortar should be mixed with water to a damp consistency but seldom to the consistency of wet concrete. The reason for this is that there is always a certain quantity of excess water in the base concrete which will work upward through the finish course. Any of this water which cannot be absorbed by the finish mortar will remain upon the surface and make it far too wet for floating and troweling.

Base concrete which has been permitted to take its initial set will have lost the greater part of its excess water and a finish coat applied to it can be worked with a float and trowel after a shorter period of time than would otherwise be the case.

Where conditions seem to make it imperative to start placing and troweling the finish soon after depositing the base, the finish mortar may be applied in an absolutely dry condition. The dry materials soon absorb all excess water and a slight quantity must be sprinkled over it during the floating. This method, however, while convenient at times and giving a hard wearing surface is slow and uneconomical.

Base and Topping.—In laying a concrete floor by the base-and-topping method, the base concrete is placed and screeded to a roughly level surface in the usual way. It is allowed to harden without any further work being done on it. The floor, as it is, can then be used as a working floor for several weeks or months until the time has arrived when it appears desirable to apply the surfacing course of topping material.

The topping coat should be made anywhere from 1 to 2 inches thick. To provide a bond between the topping and the base concrete, the surface of the old base concrete must be made thoroughly clean. This condition is attained by chipping the entire surface with picks and chisels until an entirely new and fresh surface is exposed. This new surface should be brushed with a weak solution of muriatic acid and water. The floor should then be washed carefully with water from a hose to remove all traces of acid and other undesirable matters.

To increase the bonding of the two layers in the floor, the cleaned surface of the base concrete should be brushed with a neat cement grout. The topping layer should then be applied immediately, screeded, and troweled.

FINISHES

Cement and Sand Finish.—A surface coat made from a plain cement and sand mortar is the wearing surface most commonly put on concrete floors. The mortar for the finish coat may be mixed in proportions varying from one part of cement and three-fourth part of sand to one part of cement and two parts of sand.

The mortar for the finish coat should be carefully and thoroughly mixed, too much water should be avoided as a damp mix gives a tougher wearing surface and also because a certain

quantity of excess water will be absorbed from the base concrete.

The finishing mortar is spread over the surface of the base concrete to the tops of the screeds, working preferably toward the concrete mixer so that the wheelbarrows conveying the mortar will not have to be wheeled over that portion of the floor on which the troweling is being done.

The mortar immediately upon being deposited should be screeded to a level surface flush with the tops of the screeds.

Fig. 116.—Screeding topping mortar.

It should then be permitted to undergo part of its initial set and to stiffen slightly, after which it should be gone over with the float, followed by the steel smoothing trowel. The floor should be permitted to rest and stiffen a little more and should be worked thoroughly with the steel trowel. During this troweling, a dry mixture of cement and sand should be sprinkled over the surface to take up the excess water and should be troweled into the finish. Dry cement without sand should not be used for this purpose, as it is likely to flake off eventually. The troweling with the steel trowel is continued until the top of the floor presents a smooth even surface free from all marks of any kind.

Granolithic Finish.—A granolithic finish is similar to a plain cement-and-sand finish excepting that the mortar contains also a coarse aggregate of pieces of stone approximately $\frac{3}{8}$ inches in diameter. A granolithic finish, then, is in reality a fine-grained

concrete mixture. The coarse aggregate should be such as will pass a ½-inch screen and be retained on a 3/16 inch screen.

The material for the granolithic finish should preferably be mixed in the proportion of one part of cement, three-fourths part of sand, and one and one-half parts of the coarse aggregate. The coarse aggregate may consist of crushed or screened gravel, granite, blue stone, or other hard rock. Granolithic-finish mortar is applied in the same manner as the plain cement-and-sand surface material but the troweling of the surface is not continued for so long a time.

Attention should be called to several advantages to be experienced in building a floor with a granolithic finish. A granolithic topping will not crack so much as a finish made of cement and sand. The greater part of its bulk consists of stone, which cannot contract. The mortar is rich in cement, which is an aid to finishing work. The course aggregate or grit, as it is called, can be purchased cheaply and saves a corresponding volume of expensive cement and sand. There is consequently a saving in the cost of materials. A floor finished with a topping containing grit presents a strong hard wearing surface that will not become slippery. Granolithic topping mortar may be mixed in the proportions of 1–1–3, 1–1½–3, or 1–2–4.

Cement Finish Containing a Hardener.—A floor hardener may be added to either the plain cement-and-sand surface mortar or to the granolithic finish just described. The hardener may be incorporated in the body of the mortar or sprinkled on the surface of the floor. Instructions for proportioning the quantity of hardener to be used are furnished by the manufacturers. During the final troweling a specified quantity of the hardener should be mixed with pure cement and sprinkled over the floor surface.

Colored Mortars.—Cement mortars can be colored by the addition of pigments. Sidewalks are usually darkened by the addition of lampblack to the finish mortar. A pleasing shade may be obtained by adding ½ pound of lampblack to each bag of cement. Entrances to stores may be made attractive by coloring the concrete of the floor entrance with metallic red. Ten pounds of metallic red to each bag of cement will give a good color. The surface of the floor can be embellished by marking the surface with score marks about 6 inches apart to imitate tile.

A cheaper and probably a more attractive way of treating the floor is to finish the surface with a wooden float and to mark the

surface with a border formed of score lines 6 or 8 inches from the sides.

Coloring matters dilute the strength of the cement and should never be added in greater proportion than 10 per cent of the weight of cement. The pigment should be measured carefully and mixed with the cement while in a dry state.

LEAKS THROUGH CONCRETE

A leak through a concrete wall or floor can usually be stopped. There are several ways of doing this, depending on the nature of the leak. It is much easier to stop the leakage where it enters through a hole, than where it enters through a long crack or through a porous area.

Where water enters through a small hole, the concrete should be drilled out to a diameter of about 1 inch and to a depth of 6 or 8 inches. A small piece of pipe, threaded on the outside end, is then inserted in the hole and surrounded with mortar. The pipe provides a passage for the leakage for several days until the mortar around it has set hard. The pipe is then filled quickly with dry cement and a cap is immediately screwed over the end of the pipe. Usually this method will stop all leakage. If the cap is kept back from the surface of the concrete, the remainder of the hole can be filled with cement mortar.

A leak of this nature can often be stopped quickly by drilling a hole of small diameter into the path of the leak and driving a dry wooden plug into it. The wood will swell as it becomes wet and hold the water back so that the remainder of the hole can be filled with mortar.

Leakage through a crack is difficult to stop. The first thing to be done is to provide a free passage for the seepage, as little can be done to stop the inflow where the water enters with any pressure. If the leakage is in a vertical crack in the wall, an attempt should be made to insert a pipe, similar to the one just described, in the lower part of the crack, so as to cause all the water to pass through it and relieve the remainder of the crack of all seepage under pressure. The crack can then be filled with mortar and finally the drainage pipe can be filled.

Very often leakage occurs through a porous place in concrete and the seepage is scattered evenly over an area. The usual procedure is to cut out the porous area and to stop the leakage gradually and restore the concrete by applying thin coatings

of cement mixed with some substance that will cause it to take its set quickly. There are a number of substances that can be mixed with cement and are serviceable in stopping leaks. A description of several of these may be of interest.

Alum.—Alum when mixed with cement and water, forms a slight coating of calcium sulphate. Sulphates are insoluble in water; therefore this property is useful in stopping seepage through concrete. Where there is a slight seepage the alum may be applied dry to the surface. The alum gradually fills the pores of the concrete with a hard insoluble sulphate.

Several coatings are necessary if the seepage is strong. An alum solution may not stop it. Where water seeps upward through freshly deposited concrete in a floor, the alum should be mixed with dry cement and applied over the seepage area, gradually working from the outside of the area toward the center. The chemical action between the alum and cement starts at once but proceeds slowly and will usually act successfully.

Washing Soda.—Washing soda added to the water used to mix cement will cause the cement to set rapidly, much like plaster of paris. With a strong solution the cement will harden in 5 minutes; with a weak solution a longer time is required. Soda is useful in filling holes where leaks occur.

Water Glass.—Water glass acts quickly on cement. It may be used to plug a leak. The cement should be mixed with water to a stiff consistency and the water glass should then be added. The chemical action is very fast. The mortar becomes hard in a fraction of a minute and the man using it must work quickly. Water glass is slowly soluble in water and a patch put on with it will eventually let water pass through it. There are many places, however, where its use is advantageous.

Litharge and Glycerine.—A quickly acting mixture for plugging a leak may be made by mixing dry a quantity of litharge with washing soda and adding to it when ready to use a mixture of glycerine and water glass. Mix the ingredients, a small quantity at a time, to a plastic condition and force quickly into the hole. This compound is useful in plugging the bottom or back portion of a hole; the portion near the surface can then be filled with ordinary cement mortar if desired.

Calcium Chloride.—This substance is the active chemical agent in many integral waterproofing compounds. When mixed with water, it acts on cement to quicken the set. It acts slowly and

generates heat when uniting with cement. It is useful, therefore, in freezing weather and as a waterproofing material. Calcium chloride increases the contraction of cement and for that reason its use at times may be harmful.

Iron.—Iron, when rusted, expands to several times its original volume. Finely ground particles of iron mixed with sal ammoniac and water quickly oxidize and can be employed to plug leaks and to waterproof masonry. Its use gives a discolored, unsightly surface unless covered over with a cement wash. A waterproofing material of this nature is manufactured to be sold commercially and can be procured from dealers. The material is mixed with cement and water and should be applied as a wash filling all pores and cracks. With stubborn leaks, a number of coatings are necessary. Each coating should stop some seepage. Each coating should be kept damp to facilitate the oxidation of the iron.

CONCRETING UNDER WATER

Concrete can be successfully deposited under water provided precautions are taken to prevent the cement from being washed away as the concrete is deposited. The usual way of doing this is to place a pipe or wooden shute upright in the water and with the lower end of the pipe resting on the bottom. The pipe is then filled with concrete and shifted when needed as the concreting proceeds. Cement may be washed out of the first concrete deposited as it passes down through the pipe. To prevent this action, the pipe should be filled before it is lowered into the hole. To do this, the lower end can be closed with a piece of wood or sheet iron temporarily wired in place. When the pipe is lowered to the bottom, the wires can be cut and the concrete allowed to flow out.

The top of the concrete in the pipe should always be maintained above the surface of the water. The pipe is raised slightly with each filling, causing the concrete to spread out from the lower end of the pipe.

CHAPTER V

WOOD CONSTRUCTION

Lumber.—Lumber is the general term used to designate all material sawed from logs for commercial purposes. Pieces of large cross-section, such as beams or girders, are called timbers. Lumber is also classified as dimension lumber, scantling, planks, boards, and moldings. The principal structural woods are obtained from trees of various members of the pine family. The harder woods, used chiefly for flooring and inside trim, are obtained from the broad-leafed trees, such as the maples and the oaks.

Spruce is the principal structural lumber of the northern part of the United States. It is largely employed for making boards and dimension lumber, and is a popular material for forming sills, joists, studs, rafters, flooring, sheeting, siding, and laths. Spruce is classed among the softwoods and is easily worked with tools, but it is a strong tough wood and very dependable when subjected to a heavy strain. It resists the effects of exposure well and is very suitable on that account for outside work. The wood itself is close grained and has a satiny texture. It is nearly white in color and has a pearly luster with a slightly yellowish tint between the annual rings.

White pine was at one time the principal material used for making boards and sheeting lumber in the Northern states. It has become scarce and more expensive. On this account, its use in the better grades is confined largely to millwork and inside trim in building work. Its weathering qualities are excellent and are only exceeded by those of cedar. It is particularly easy to work with tools. For these reasons, it is well adapted to the fabrication of windows and moldings. It is not a strong wood and, therefore, is never used for framing lumber. It holds paints and stains well and its power of holding glue makes it of value to the joiner. White-pine wood is very light in weight and is soft with a close, straight grain. It is white in color, often has a reddish tint, and may be identified usually by small black

markings similar to pencil lines about ¼ inch long appearing occasionally in the body of the wood.

Hemlock is wood which is, in a way, similar to spruce in appearance but far inferior to it in many ways. The wood is not so white, but inclines to a slightly brownish color. It is soft and light in weight. It is brittle and splits easily. It is not durable and one of its marked characteristics is its liability to contain shakes. It has a coarse, uneven grain. Hemlock is becoming scarce, but it is only suitable for cheap boards and rough framing in unimportant work.

Southern yellow pine is the leading structural wood growing in the Southern states. It is largely used in all parts of the country for all purposes of construction. Southern yellow pine is also known as Georgia pine, hard pine, long-leaf pine, or North Carolina or short-leaf pine. Yellow pine is a yellowish white wood interspersed with annual rings filled with a dark-red resin. These rings appear as well-defined wavy markings on the face of flat-sawed boards which make it desirable at times for finishing lumber. Yellow pine is heavy, hard, tough, coarse grained, and compact. It is very strong and durable when it has been well ventilated and dried and is the best material for heavy framing timbers. It cannot be used in contact with the ground for permanent sills, sleepers, or posts as it decays rapidly in such positions.

Long-leaf yellow pine is the name given to the best quality and highest grade of Southern yellow pine. The lumber trade associations formulate a set of rules governing the grading of yellow pine by differences in quality and freedom from defects.

Cypress wood in the South corresponds in use to that of the white pine in the North. It is one of the most durable of woods and is well adapted to outside use and in contact with the soil. In appearance, it is very similar to yellow pine, the wood being yellowish white with red markings of resinous deposits in the annual rings. The wood is soft, light, and close grained but is inclined to be brittle. Its wood is used for sills, boards, windows, doors, sidings, and laths. It is also highly esteemed and used for making tanks for water storage. Cypress is being used more in the North than formerly, particularly for making doors and interior trim where its markings give a handsome finish when left in natural color.

Maple is a light-colored, fine-grained wood. The medullary rays are small and distinct giving a silver grain to quarter-sawed

lumber. It is very light brown in color. The wood is very hard, heavy, tough, close grained, and compact. It is susceptible to a good polish and is extensively used as a flooring material in factories, public buildings, and residences on account of its fine wearing qualities.

Oak, a heavy, hard, strong wood, includes several varieties, the most important of which are white, chestnut, and red oaks. All oaks have a coarse texture in the annual rings due to large sap ducts. White oak is the hardest of the American oaks. The wood has a light yellowish-brown color with a close, cross-grained texture, and when quarter sawed shows a handsome silver grain. White oak is used for interior finish and flooring and for structural purposes where great strength and durability is required. Chestnut oak is similar to white oak but darker in color and does not possess as fine an appearance as white oak. It is used for structural purposes and, as it is durable in contact with the soil it is largely used for railroad ties and posts. Red oak is much darker than the other oaks being of a reddish-brown color. It is also coarser and has a more porous texture. It is used for floors and interior finish.

Qualities of Wood.—The best lumber is obtained from mature trees, the fibers of which have become compact and firm. When the trunk of a tree is cut across, as in Fig. 117, it is seen that the structure is composed of three parts, the bark, the sapwood, and the heartwood. The bark is valueless for structural purposes. Inside the bark, there is a comparatively soft portion made up of thin-walled cells which constitutes the living portion of the tree. This is called the sapwood. It may have a thickness anywhere from ¼ to about 4 inches. Inside of the sapwood and forming the center of the tree is a dense and more compact wood which is called the heartwood. The sapwood is always lighter in color than the heartwood and is also softer and less compact. The heartwood is the most desirable portion of the tree for lumber purposes.

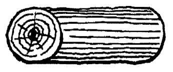


FIG. 117.—Section of tree.

Referring again to Fig. 117, it will be seen that the section is marked by many concentric rings. As a tree grows, new sap ducts and cells form just beneath the bark. This growth is more rapid in the spring than in the summer and at the end of the season the growth stops. The contrast of the open growth of spring to the condensed growth of summer gives rise to the

rings, each of which marks a year's growth. When these annular rings are narrow and close together, they denote a slow strong growth and when wide apart they denote a quick weak growth.

The annual rings are intersected by radial lines of wood tissue some of which communicate between the pith at the center of the tree and the soft tissue at the outside beneath the bark. Other radial markings extend through only a portion of the cross-section. These radial tissues are called the medullary rays. the long ones the primary rays, and the short ones the secondary rays. It is the presence of the medullary rays which gives the beauty to quartered oak.

Knots are the stubs of branches. Figure 118 illustrates the growth of a branch from the trunk of a tree. Some of the ducts conveying the sap up the tree run into the branch, others turn out on either side of the branch joining again above it, as shown. Inspection of the structure of a knot in a board or timber will often indicate which end of the stick was located toward the top and which to the base of the tree when growing.

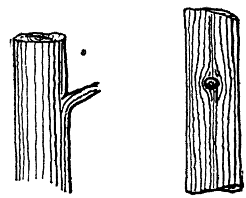


FIG. 118.—Diagrammatic sketch of knot formation.

Seasoning.—The seasoning of lumber consists of expelling the moisture which is contained in the pores of the wood. Lumber may be seasoned by natural seasoning or by artificial seasoning. Natural seasoning is accomplished by exposing the lumber freely to the air in a dry place under a shelter. The bottommost pieces should be raised at least 2 feet above the ground. The lumber is piled in horizontal layers with slats between each layer, the lumber being repiled at intervals and decayed pieces removed. The time required for natural seasoning varies according to the nature of the wood and its thickness. Boards will usually take 1 year and planks 2 years for thorough seasoning. Very little lumber is thoroughly seasoned when shipped by the manufacturer.

Artificial seasoning or kiln drying consists in exposing the lumber to a current of hot air in a drying kiln. Kiln drying produces an inferior product, as it causes unequal drying which impairs both the strength and elasticity of the wood. About 4 days are required for drying pine boards.

The shrinkage of timbers lengthwise is negligible being less than one-tenth of 1 per cent. The shrinkage crosswise of a timber is

considerable, being somewhere between 3 and 6 per cent which is over 3/8 inch for a stick 10 inches wide. Most lumber is incompletely seasoned. When placed in a structure, the shrinkage continues and later causes unsightly joints.

Defects in Lumber.—New wood should smell sweet; a disagreeable smell is a sign of decay. The wood should be firm and bright; when it appears dull and chalky, it is not first-class stock. Good lumber should be uniform in color; when blotchy or discolored, it signifies a diseased condition.

There are various defects occurring in lumber which are caused either by the nature of the soil in which it grew or by accidents due to storms or other causes. Some of the more usual defects are the following: Shakes are splits or checks in lumber which usually cause a separation of the wood between the annual rings. A ring shake is an opening between annual rings. A through shake is one which extends between two faces of the timber. Wane is bark or lack of wood from any cause on the edges of timbers. Twisted is the term applied to lumber in which the grain winds spirally. Foxiness is a yellow or red tinge indicating incipient decay. Dote is a disease indicated by speckled stains. Dry rot is a fungous growth and can be discovered by a blue tint and by a brittleness of the wood. Timber thus effected is of no permanent value as dry rot continues until the fibers turn to powder.

Knots.—A knot is a stub of a branch. It may be small and sound, in which condition it is not objectionable, or it may be large and loose or extend far inward, in which case the strength of the stick is seriously affected. A pin knot is a sound knot not over 1/2 inch in diameter. A standard knot is a sound knot not over 1 1/2 inches in diameter. A large knot is a sound knot over 1 1/2 inches in diameter. A spike knot is one sawed in a vertical direction. If a knot is loose or dark in color, it will ultimately fall out. A loose knot is the stub of a dead branch. When a knot in a timber is not entirely sound but shows a small decayed spot on the surface, should the decayed portion be dug out with a knife, it will be found to lead to a much larger region of rotted wood inside the timber. This of course destroys the strength of the timber and classes the lumber as defective.

Inspection.—When large quantities of lumber are purchased, it will pay to engage a licensed lumber inspector to inspect all lumber. The classification and grading of lumber is very com-

plicated, the sizes and names in each classification changing with each species of wood and the requirements for each grade changing likewise with different localities. A rigid inspection can only be undertaken by experienced men. Lumber inspection is a vocation in itself and the decisions of a licensed lumber inspector are usually accepted as final by both dealers and their customers.

Inspection of lumber is undertaken from the two viewpoints of quality of stock and of dimensions of the pieces. The grade of all regular stock is determined by the number and position of the defects in any piece. The enumerated defects in any given grade are intended to be descriptive of the coarsest pieces such grade may contain. Lumber or timber sawed for specific purposes must be inspected with a view to the adaptability of the piece for the use intended.

Rough sawing to standard size means that the timbers shall not be over ¼ inch scant from the actual size specified; for example, a 12-by-12 inch timber shall measure not less than 11¾ by 11¾ inches.

Standard dressing means that not more than ¼ inch shall be allowed for dressing both surfaces; for example, a 12-by-12 inch timber after being dressed on all four sides will measure not less than 11½ by 11½ inches.

On stock shipments of boards 8 inches in width and under, no board shall be admissible that is more than ¼ scant; on 10 inches not more than ⅜ inch and on 12 inches not more than ½ inch scant of specified width. Scantling embraces all sizes from 2 to 5 inches in thickness and 2 to 6 inches in width.

Plank embraces all sizes from 1½ to 5 inches in thickness by 7 inches or more in width.

Dimension lumber embraces all sizes 6 inches or more in thickness by 7 inches or more in width, including 6 by 6.

Boards embrace all thicknesses under 1½ inches having a width over 6 inches.

Standard Lengths.—The standard lengths are multiples of 2 feet, running from 10 to 16 feet for boards and scantling and 10 to 20 feet for dimension lumber. Longer or shorter lengths than those specified are special. Special and fractional lengths are counted as the next higher standard length.

The standards of width for lumber are in multiples of 1 inch. All sizes 1 inch or less in thickness are to be counted as 1 inch thick.

Quarter and Flat Sawing.—The manner in which lumber is sawed from the green timber has a great effect upon the quality of the wood and the appearance of the grain. The two methods of sawing lumber are known as flat sawing and quarter sawing. Flat sawing is the most economical method and is the method utilized in making ordinary boards. In flat sawing, the saw is passed through the log, cutting slabs flat from the log tangentially to the annual rings, as indicated in Fig. 119. Quarter sawing signifies that the log is sawed into quarters before being reduced

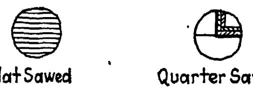


FIG. 119.—Methods of sawing into boards.

to boards, the cutting into boards proceeding then by cuts as nearly as possible on lines radial to the annual rings, as shown in Fig. 119. There are several ways of quarter sawing, differing slightly in the methods of making the cuts. The best grades of finished flooring are quarter sawed. Quarter-sawed lumber is also called rift sawed and edge grained. Quarter-sawed lumber shrinks and checks less, does not sliver, and wears more evenly than flat-sawed lumber.

Surfacing.—All lumber has a rough surface when sawed from the logs and is made smooth by planing machines. Ordinarily $\frac{1}{16}$ inch decrease in thickness should be allowed for each side surfaced. Rough 1-inch boards planed on one side are usually spoken of as $\frac{7}{8}$ inch thick; planed on both sides as $\frac{3}{4}$ inch. Planed lumber is spoken of as surfaced or dressed. Nearly all sawmills now dry their lumber and run it through a planer to save the extra freight on the rough and green lumber. The symbols S1S, S2S, or S1S1E mean, respectively, surfaced one side, surfaced two sides, and surfaced one side and one edge. They are used descriptively in listing lumber.

Measurement of Lumber.—Lumber is measured by the board foot, a board foot being a piece 12 inches square and 1 inch thick. A piece of 12-inch board, 1 inch thick and 3 feet long will therefore contain 3 feet board measure or, as it is customary to write, 3 b. m. A piece of 12-inch plank, 2 inches thick and 3 feet long contains 6 b. m. Lumber is always sold on a basis of 1000 feet board measure, the customary abbreviation being M. b. m. or simply M. One-inch boards are often spoken of as containing

a certain number of square feet, this does not lead to any confusion as there will be as many feet board measure as there are square feet. To obtain the number of feet board measure in any piece of timber, the most convenient method is to figure the number of feet board measure in a 1-foot length and multiply

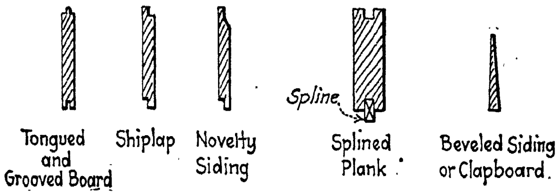


FIG. 120.—Lumber sections.

the result by the length in feet. For example, in a 1 foot length of 2 by 8 there are 16 square inches. The area of the end of an ideal unit board measure, an imaginary piece of 1-inch board, 12 inches wide and 1 foot long, is 12 square inches; therefore, a

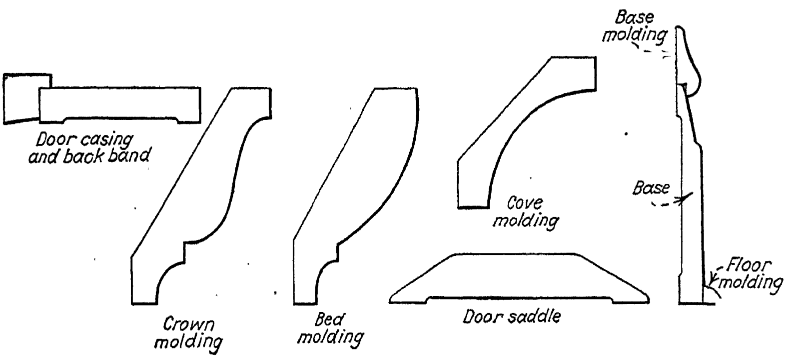


FIG. 121.—Types of moldings.

2 by 8 contains $1\frac{1}{3}$ b. m. per foot. A 10-foot length would contain ten times this: $\frac{4}{3} \times 10 = \frac{40}{3}$, or $13\frac{1}{3}$ b. m. A 9-foot length will contain $\frac{4}{3} \times 9 = \frac{36}{3}$, or 12 b. m.

In figuring lumber all boards less than 1 inch thick are counted as 1 inch thick. All dressed and matched stock is measured and sold "strip count," meaning the full size of the rough strip from which such stock is made.

Sections.—Tongued-and-grooved or matched lumber is the term applied to boards that have been provided with a tongue and groove on opposite edges (see Fig. 120).

Splined plank is the designation for planks that have a groove in each edge so proportioned that, when two planks are laid together, a spline or narrow strip of wood may be inserted in the groove thus formed, closing up the joint (Fig. 120).

Shiplap is the name given to boards which have been shaped along the edges, so they will lap and form a halved joint. Shiplap is manufactured by the yellow-pine manufacturers to a much greater extent than by manufacturers of spruce or other woods (Fig. 120).

Beveled siding is similar to clapboards in cross-section but flat sawed in long lengths similar to ordinary boards. It may be procured in various widths from 4 inches upward (Fig. 120).

Novelty siding is similar to shiplap (Fig. 120).

Clap boards are beveled strips of wood similar to beveled siding except they are quarter sawed and are made in a standard length of 4 feet.

Moldings are made of various cross-sections suited for different purposes. The sections, shown in Fig. 121, are merely typical

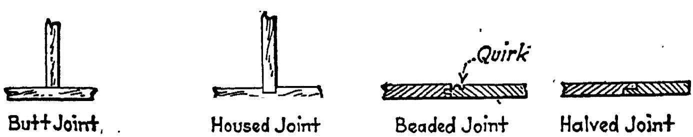


FIG. 122.—Joints.

and the name of each type is sufficiently descriptive to indicate the use for which each molding is suited.

Joints, most commonly used in carpentry work, are illustrated in Fig. 122. The beaded joint is provided with a quirk on either side of the bead to make the real joint less noticeable.

TYPES OF FRAMING

Types of Framing.—Superstructures of wood as designed for industrial buildings usually are either of the ordinary light-frame type, constructed of framing timbers of small cross-section such as 2-by-4 studs, 2-inch joists, and sheeted with ⅞-inch boards, or they are of the slow-burning type known as wooden-mill construction. The slow-burning type is built with wooden columns and girders of large cross-section and with floors made of planks 3 or 4 inches thick.

The light-frame type is the cheaper construction due to low cost of lumber of small cross-section. The slow-burning type, however, possesses greater strength and results in a simpler and

roomier construction. The fire-resisting qualities of mill construction are much greater. This is the type of construction most favored today for frame industrial buildings. The same methods are also used in forming the interior framing of many buildings built with brick walls. For small structures, however, the light-frame type will be found the most suitable and economical.

LIGHT-FRAME CONSTRUCTION

Sills.—When the foundation walls of a structure have been built, the wooden framework is started by laying a sill upon the

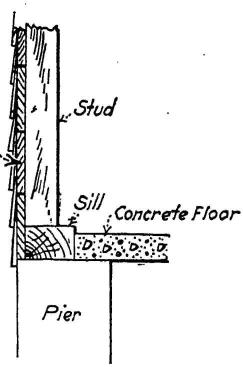


FIG. 123.—Sill supported by piers.

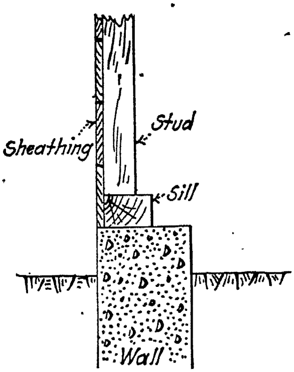


FIG. 124.—Sill supported on wall.

walls around all sides of the building, to serve as a base to which the wall and floor framing may be secured. In its simplest form the sill is a solid stick of rough unsurfaced lumber supported upon piers or posts extending downward to below the frost line. Figure 123 shows the usual manner of constructing a small building without a basement, such as a small garage or a small storage shed. Another modification employed for small buildings of the same nature consists of a solid sill laid upon a small wall, as in Fig. 124. The sill may be of any size but is preferably 4 by 6 or 6 by 8 inches in cross-section and of unsurfaced lumber. The sill for a small house is usually made of 4-by-6 timbers. A 4-by-6 timber is what might be called a one-man timber, as one man can handle it easily.

At the corners where sills intersect and along the walls when individual pieces of the sill come together, the timbers should be connected with a halved joint, as shown in Fig. 125. The sill,

should be first carefully framed, then laid upon the wall in a bed of mortar and leveled accurately all around the building. The outside edge of the sill is kept back 1 inch from the face of the wall so that the outside boarding will come flush with the latter, the siding or base board lapping over the wall and sealing the joint.

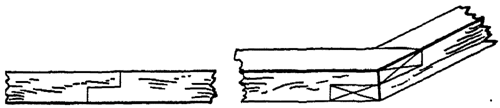


Fig. 125.—Halved joints.

The sill should be accurately squared and leveled as all dimensions and heights are measured from it once it has been fixed in position.

Where there is a basement, it is necessary to support the first floor on joists. The latter are supported at the walls by the sills, as shown in Fig. 126. Another type of sill has been developed

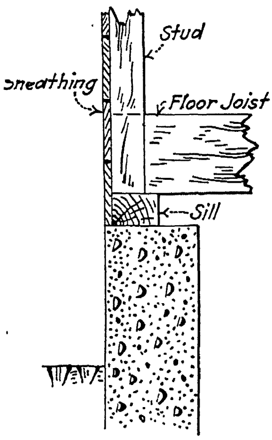


Fig. 126.—Sill supporting ends of joists.

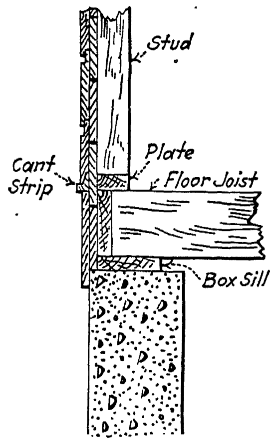


Fig. 127.—Box sill.

which is made of 2-inch plank and is called a "box sill." A box sill is shown in Fig. 127. It is becoming increasingly popular in the construction of small dwellings. A solid sill is preferable to a box sill. It is more rigid and provides a better support than a box sill. A box sill is cheaper to erect, as there are no halved joints to be framed.

Girders.—Ordinarily, the distance from wall to wall is too great to be spanned by the first-floor joists and it is necessary to support the latter by one or two intermediate girders supported

by posts. The girder should be a 6-by 8-inch, or larger, timber, supported either on 6-by-6 posts, brick piers, or pipe columns. It was formerly the custom to check the joists over the sill and the girder to reduce the depth of wood likely to shrink. The girders were notched and the joist framed to fit into them. It is now the usual practice to cut the joists with plain square ends and to support them on the sills and girders, without any cutting of gains or checks (Fig. 128). All joists, however, must be sized to the same depth at the ends.

Wall Framing.—The wall framing consists of 2-by-4-inch studs spaced 16 inches on centers to conform to 48-inch lath lengths.

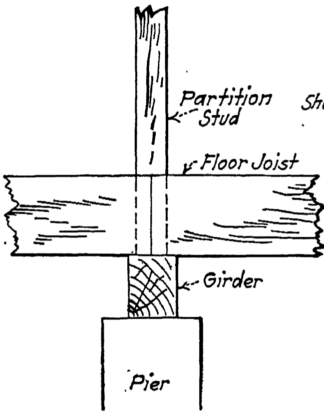


FIG. 128.—Floor joists supported on girder.

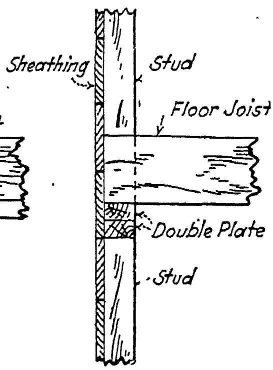


FIG. 129.—Double-plate support for joists.

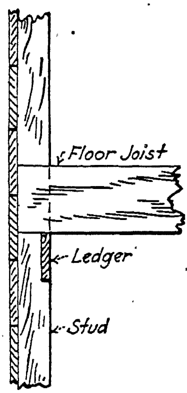


FIG. 130.—Ledger support for joists.

This spacing is maintained except where openings have to be provided for windows and doors. All studding should be surfaced on one edge to bring them to one size. When a solid sill is used the foot of the studs should rest upon the sill. With a box sill, the studs are secured at the bottom to a 2-by-4 sole piece (see Figs. 126 and 127). The wall ends of second floor joists may be supported at the walls by a double plate formed of 2 by 4's, as shown in Fig. 129. The studs may be run continuously up past the second floor, the second floor joists being supported by a ledger let into the studs 1 inch (see Fig. 130). The tops of the studs end at the underside of the double plate which supports the rafters (Fig. 145). This plate is formed by 2 by 4's doubled, the two layers breaking joints with each other. It is well to keep the joints away from window openings so that the whole strength

of the double plate is available to carry over the opening. The studs in the gable ends are secured to a double plate at the level of the second floor, in a manner similar to wall studs, or they may be run up continuously to the end rafters splicing them if necessary. The end rafters are let into the studs, as shown in Fig. 148.

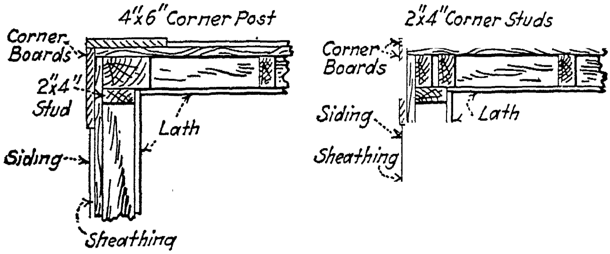


FIG. 131.—Two ways of forming corner.

The type of construction represented by a frame building, built with a double plate under the second floor joists, is known as "story by story" framing. If the design calls for a ledger

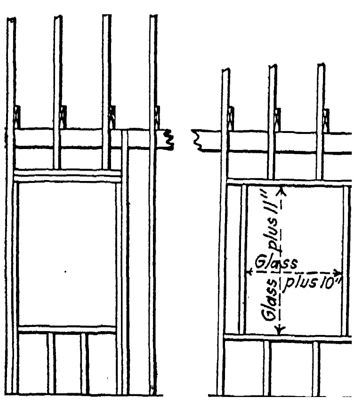


FIG. 132.—Window openings.

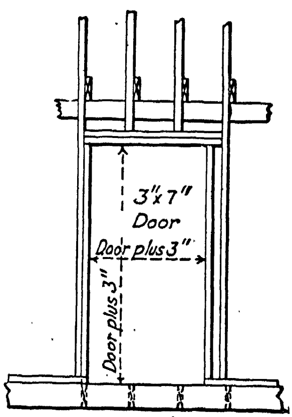


FIG. 133.—Door opening.

under the second floor joists, the construction is known as balloon framing.

At all corners, if the building is to be plastered or finished in any way inside, the studs will have to be doubled up or a 4 by 6 and 2 by 4 should be nailed together, as in Fig. 131, to receive the ends of the lath.

Wall Openings.—Openings have to be provided in the wall framing for windows and doors. These openings may be framed

as the studs are put in place or all the studs may be spaced 16 inches on centers and the openings may be cut out of the studs later. With the latter method there is not so much waste as might be expected, as the pieces cut out of the studs may be used for headers and stools. Framed openings for windows and doors are shown in Figs. 132 and 133. The openings may be framed with single studding or a stronger opening may be made by doubling the studs as shown. When it is necessary to frame the openings without the detail drawings or frames from which to work, the size of the opening may be figured from the description given for the glass and dimensions of the door. The distance of the window stool above the floor is generally stated on the plans and will usually be about 2 feet.

Diagonal Bracing.—Where a window is located close to the corner of an outside wall exposed to wind pressure, the corners of the building should be braced by a diagonal brace. As a further stiffening against the wind it is well to cut short pieces between the studs of the interior partitions to stiffen them in their centers.

Wall Covering.—When the window and door openings have been framed, the studs may be covered with the board sheathing, building paper, and siding material.

The sheathing boards are nailed directly to the studs with two eight-penny nails in each stud. The boards may be of any material but should all be of one thickness, either surfaced on one or both sides. Shiplap or tongued-and-grooved ⅞-inch boards are preferable to square-edged boards as a tighter joint is obtained. Shiplap may be placed a trifle more quickly than tongued-and-grooved boards. The sheathing boards are usually placed horizontally across the studs, though a stronger bracing is obtained when they are placed diagonally. The latter method, however, is more costly on account of the waste of material in cutting and the extra labor entailed. The boards extend to the face of the 2-by-4 framing around the openings.

The sheathing paper or felt may be tacked in place as soon as the sheathing boards are nailed on. The window and door openings are first sheathed with paper. Then the frames may be nailed in position. The paper around the opening should extend beyond the casings so that ample lap may be provided for the main portion of the paper.

Ordinary red-rosin sized paper is often used for this purpose but there are many sheathing felts on the market which will give

better results. Paper, being of close texture and a non-conductor of heat, makes a good covering material, making the building warmer in winter and cooler in summer. Ordinary tar paper is not good for this purpose as it disintegrates after a few years.

The siding materials most commonly used are beveled siding and novelty siding. Clapboards are frequently used and likewise shingles. Beveled siding may be procured in various widths. It is usually lapped about 2 inches and nailed with six-penny galvanized-iron nails. The nails should be long enough to reach through the board sheathing and take a firm hold in the studs. In laying siding, it is necessary to vary the amount of face exposed to the weather where the siding comes in contact with windows and doors, so that the horizontal lines of the siding will align with the lines of the sills and heads of the frames.

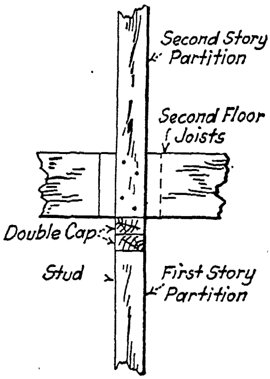


FIG. 134.—Center partition.

At all outside corners the siding is butted against vertical corner boards (see Fig. 131). The corners of reentrant angles of the building are formed by a single strip of wood called a "backing strip." Corner boards and backing strips should be $1\frac{1}{8}$ inches thick and beveled slightly along the edge so that the siding will fit tightly. All siding butting against the corner boards should be cut a trifle long in order to form a tight-appearing joint even though a slight shrinkage should take place. The bottom of the walls may be finished by a baseboard and cap to turn off the water or the siding may extend below the top of the foundation wall to form a lap of 1 or 2 inches (Fig. 127).

Partitions.—The ends of second-floor joists away from the walls are supported on the first-story partitions (see Fig. 134). Where there are continuous partitions, the second-story studs should be nailed to the plate beneath and spiked to the second-floor joists. The lengths of 2 by 4, which form the partition plates and which are lapped and spiked to the plate surmounting the wall studs, tie the building together lengthwise and stiffen the partition. Where partitions are not continuous and run crosswise of the joist, the partition may be built as in Fig. 135. When a partition runs parallel to the joists, the joists will have to be doubled, as shown

in Fig. 136. Doubling the joists furnishes extra strength for supporting the partition and also provides a support and nailing space for the flooring.

The framing of openings in partitions consists usually of provision for doors. The opening is framed in the same manner as for an entrance door with the exception that there is no sill on an inside door frame and, as there is plaster on either side of the partition, the detail is the same on both sides of the opening.

Floors.—Floors in light-frame construction are supported on 2-inch joists spaced usually 16 inches, and sometimes 2 feet on centers, according to the strength of the joists and the load to come upon them. For ordinary buildings with light floor loads and for dwellings with spans of 12 feet or less a standard construction is 2-by 8-inch joists, 16 inches on centers; with spans over 12 feet, 2-by 10-inch joists, 16 inches on centers, are standard. Where the spans of floor joists exceed 12 feet there is a tendency of the joists to buckle sideways, when heavily loaded. To prevent this, bridging should be cut in between the joists, as shown in Fig. 137. The bridging also serves to spread the strain of concentrated loads over more than one joist. Bridging is usually cut from strips of 1-by-3 stock, unsurfaced, and spaced not exceeding 8 feet.

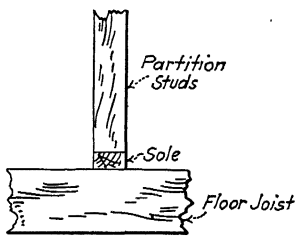


FIG. 135.—Partition crosswise of joists.

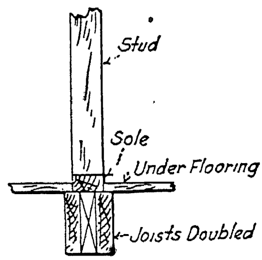


FIG. 136.—Partition parallel to joists.

Flooring.—Floor sheeting consists, usually, of two layers of $\frac{7}{8}$-inch boards; one, the underflooring, also called subflooring, the other the finished flooring, commonly designated as flooring. The underflooring is made of $\frac{7}{8}$-inch boards surfaced, usually, on one side to make them all of one thickness. Square-edged boards may be used or tongued-and-grooved stock or shiplap. The underflooring is usually constructed of the cheaper grade of

boards. They may be of yellow pine, hemlock, fir, or spruce. The underflooring may be laid on the floor joists, as soon as the latter are placed, and will then form a convenient working floor for the men. It is well to omit an occasional board the entire length of the floor, fitting the board but not nailing it in place until later. The vacant space provides relief for swelling and expansion of the floor caused by dampness or rains during construction. The boards which have not been nailed in place should be tacked temporarily to the adjacent floor boards until replaced in their permanent position.

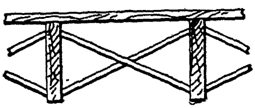


FIG. 137.—Bridging.

The underflooring is commonly laid crosswise of the joists but, when laid diagonally, it gives a stronger floor and has the advantage of permitting the finished flooring to be laid in any direction with the best results. The underflooring is through nailed to the joists with eight-penny nails, the individual boards being cut to break joints.

Finished Flooring.—The finished flooring or top flooring should be formed of narrow strips of some hard wood that will wear well. The material should be tongued and grooved and surfaced on at least one side and should preferably be of quarter-sawed or edge-grained stock. The woods most frequently used for top flooring are yellow pine, maple, and oak. For cheap flooring spruce is often used. The top floor should be blind nailed through the tongue with eight-penny cut nails and should not be laid until all the rough building work has been finished. Flooring lumber is made in narrow strips to avoid as far as possible the cracks that form between boards due to shrinkage.

Yellow-pine flooring may be had in 3- and 4-inch widths, with 2½- and 3½-inch faces, respectively. Quarter-sawed pine, also called edge- or comb-grained pine, is preferable to the flat-sawed pine, as the latter splinters badly when subjected to wear. Yellow-pine flooring is shipped in lengths the same as ordinary boards and is tongued and grooved along the edges only.

Maple flooring is manufactured in short lengths of 2 feet and upward. Maple flooring is tongued and grooved on the ends of the pieces as well as along the edges. Maple is such a hard wood, that it is customary for the manufacturers of maple flooring to provide nail holes already drilled along the ends as well as sides

of each piece of flooring. Maple flooring should be carefully protected from dampness or rain, for when wet it becomes discolored and is liable to warp.

The finish flooring should preferably not be laid in the same direction as the underflooring on account of the shrinkage strains in that position tending to open unsightly joints in the floor surface. The top floor will present a better appearance to the eye when the strips are laid in the direction, rather than crosswise, of the entrance. For these reasons, it is preferable to run the underflooring diagonally across the beams.

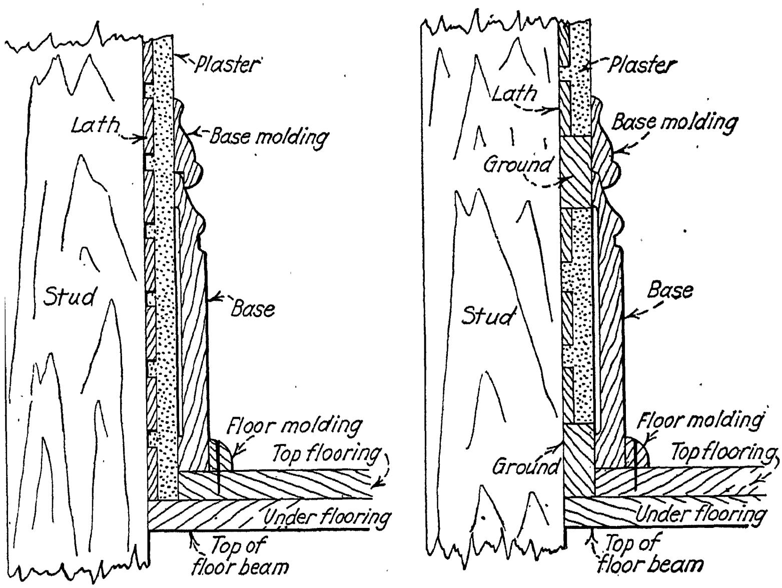


FIG. 138.—Details at base, frame.

Base.—A base is shown in Figs. 138 and 139. In these figures, a three member base is shown consisting of the base, base molding, and floor molding. The base is usually nailed in place after the top flooring is laid. In inexpensive work, the base may consist of the base only, the two moldings being omitted. The floor molding should always be nailed to the floor, never to the base. The floor molding will then hide any crack that forms under the base due to shrinkage of the base and floor. In inexpensive work, base grounds are omitted and the base is

nailed through the plaster to the studs. Frequently, a board is nailed to the studs and serves as both top and bottom grounds and fills the space behind the base ordinarily occupied by lath and plaster. In construction of buildings of the better class, grounds are installed and the base is nailed to the grounds.

Roofs.—The simplest roof construction is the flat roof shown in Fig. 140. This type of roof is largely used on small storage sheds and small shop buildings. It is constructed of ⅞-inch boards supported on 2-inch rafters placed 2 feet apart. The

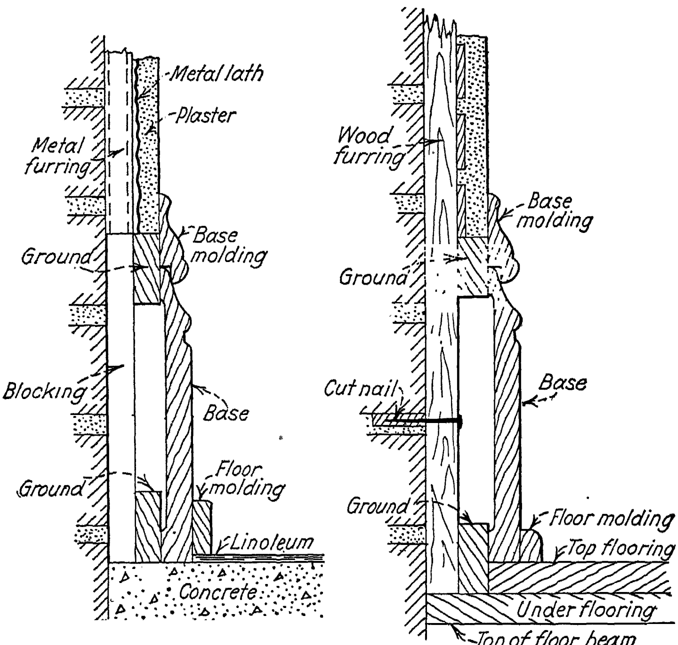


FIG. 139.—Details at base, brick.

boards are covered either with tar and gravel roofing or a patented roofing felt. The rafters are supported by the plate on each side of the building and by intermediate girders, if the length of span requires them.

Peaked Roof.—The peaked roof is the most usual construction. It is often hipped at the ends. It may have a valley where another roof joins it (see Fig. 141). The slope or pitch of a roof will often control the variety of roof covering employed. Roofs with a slight pitch are not adapted to a covering of slate or

shingles; a steep roof is not adapted to a tarred covering. The pitch of a roof is usually expressed as a ratio of rise on run, or in terms of rise as a fraction of the span. For example, a roof with a span of 40 feet and a rise of 10 feet, may be said to have a rise of 1 on 2, or a pitch of ¼.

Referring to Fig. 141, the full-length rafters extending from the plate to the ridge are known as "common rafters" or simply "rafters." The short rafters supported at one end by the hip rafter or valley rafter are known as "jack rafters."

When framing the rafters, the computed length of the rafter

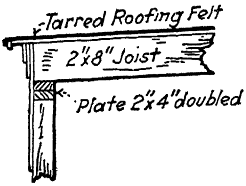


FIG. 140.—Eave detail of flat roof.

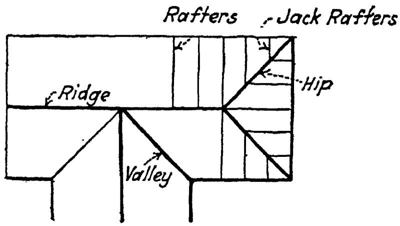


FIG. 141.—Plan of hip roof.

should be measured along the top of the timber, as indicated in Fig. 142. If the length were to be measured from the point of the notch or "bird's mouth," the joint of the rafters at the ridge would open.

The length of all framed members in a peaked roof should be given on the framing plan, but a good carpenter is competent to carry through the entire operation of framing with the aid of his steel square. It is good practice when framing a roof, after a pair of the rafters are cut, to lay them flat upon the ground in the exact position they would occupy if opposite each other in the roof and measure across them and test them otherwise for accuracy.

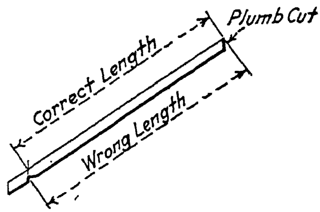


FIG. 142.—Measurement of a rafter.

It is necessary to make various cuts on the different framing members of a peaked roof in order to make the timbers fit closely for nailing. The cut at the foot of the rafters where they rest upon the plate is called a "seat" or plate cut. The cut at the top of the rafters where they join the ridge is called a "plumb"

or "ridge cut." The beveled cut necessary on the sides of the jack, hip, and valley rafters is called a "cheek cut." The edges of the hip rafters must be chamfered, as in Fig. 143, or otherwise the hip must be dropped downward a small distance so that the edges of the rafter will not project beyond the plane of the roof sheeting.

The ridgepiece (Fig. 144) furnishes a butting surface for the upper ends of the rafters and serves also to keep the line of the ridge straight. For good construction the ridgepiece should be

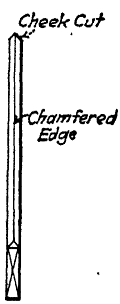


FIG. 143.—Hip rafter.

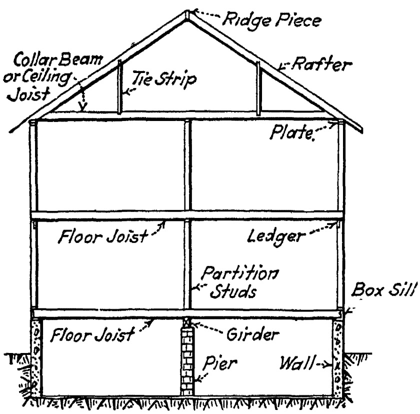


FIG. 144.—Section through frame building.

of deeper cross-section than the rafters to provide full bearing for the obliquely cut ends of the latter.

The collar beams (Fig. 144) are necessary to tie the bottoms of the rafters against spreading and, when used for that purpose alone, may be spaced at intervals of several rafters apart. The collar beams are often used as supports for ceilings and are then known as "ceiling joists." In this case the joists must be spaced 16 or 24 inches apart to accomodate the standard length of wooden lath. Ceiling joists are usually 2 by 6 in size and may be supported at intermediate points by wooden strips nailed to the rafters.

Eaves.—The eaves of a building with a peaked roof are formed by extending the rafters out beyond the wall lines 12 to 18 inches so that the rain water will drain clear of the sides. The water may be led into gutters formed in the eaves. The eaves of a frame building may be built with a box cornice, as in Fig. 145,

or with an open cornice, as in Fig. 146. The box cornice is a better construction as well as a more expensive one.

In either case the ends of the rafters may be framed with a bird's mouth, as shown in Fig. 147, or they may be cut flush with the outside of the plate. The extended narrow portion is formed by a piece of smaller cross-section spiked fast to the rafters.

Box Cornice.—A five-member box cornice is shown in Fig. 145, the several members being known as the crown molding, fascia, planchia, bed molding, and frieze. The crown molding is often

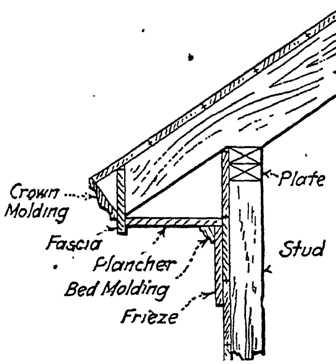


FIG. 145.—Box cornice.

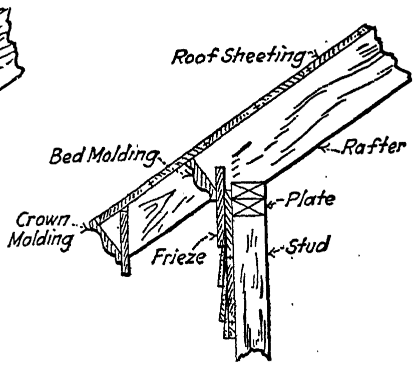


FIG. 146.—Open cornice.

replaced by a gutter running the entire length of the eaves and having an appearance, when viewed from the ground, similar to the crown molding.

In the two cases there is a slight difference in the distance to which the roof sheeting is carried and an extra molding is necessary to support the gutter. The wall sheathing should be carried up snug to the underside of the roof sheeting. It is general practice, however, in ordinary work, to stop the sheeting just below the underside of the rafter. In cold weather this is a source of a great loss of heat. Box cornices are often formed by nailing the planchia boards to the bottom edge of the rafters instead of to horizontal lookouts. The construction shown, however, is the more usual one.

Open Cornice.—An open cornice is shown in Fig. 146. In some cases a gutter replaces the crown molding but it is more usual to provide a standing gutter nailed to the roof covering. The crown molding is often omitted and the ends of the rafters are

left exposed to view. The ends then form an important architectural feature of the design.

Gables.—Details of a boxed gable are shown in Fig. 148. The roofing boards project over the end rafter and derive additional support from lookouts secured to cleats nailed on either the side sheathing or end rafters. The gable cornice is formed by the same number of members as the corresponding eave detail. In all cases the gable is finished with a crown molding; if the eaves are provided with a gutter, the crown molding on the gable should be similar to it in outward appearance. Details of an open gable are shown in Fig. 149. In this case to secure a good appearance, the gable members are supported by cantilever lookouts notched over the end rafters and toenailed to the adjacent rafter. The crown molding and fascia are both sometimes omitted to conform to a similar design of the eaves.

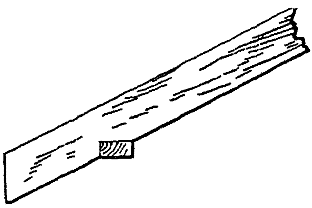


Fig. 147.—Bird's mouth.

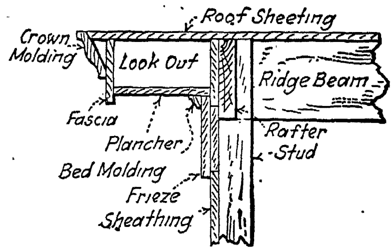


Fig. 148.—Box gable detail.

ERECTION OF A LIGHT-FRAME BUILDING

Sills.—In starting the erection of a building of light-frame construction, the sills should be first laid upon the foundation walls. They are then carefully leveled and the corners are squared. If there are any intermediate girders supporting the

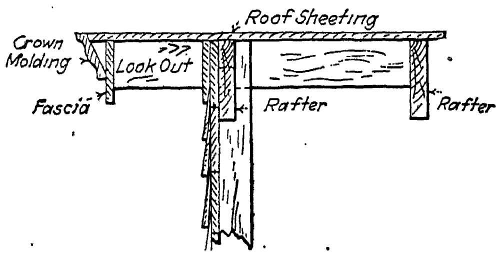


Fig. 149.—Open gable.

first-floor joists, they should be erected following the sills. The floor joists may then be sized and placed in position.

Joists and Studs.—To space the floor joists and wall studs correctly their positions should be first marked out upon the sills on both sides of the building. These positions may then be transcribed upon a piece of floor board by which the locations of the joists may be marked on intermediate supports. When the joists are placed in position, they are toenailed to the supports and are held temporarily against overturning by a floor board tacked across the tops of the joists near each end. The bridging is then cut and nailed in place between the joists.

After the first-floor joists have been placed the studding of the side walls may be erected. The corner posts should be framed first. They are then erected and should be carefully plumbed and stayed in the direction of both sides of the building.

The intermediate studs which come at the ends of the ledger boards are erected next and are in turn carefully plumbed and stayed in two directions. The ledger boards are now nailed to the studs already erected, the positions of floor joists and studs having been previously transcribed on the ledger boards from the marks on the sills. The remaining studs may now be erected one at a time.

Partitions.—When the studs and ledger boards in the side walls have all been erected, the first-story partitions may be raised, thus completing the supports for the second-story joists. The latter should now be placed, followed by the erection of the studding in the ends of the building. As in the case of the side wall studs, the positions of the end studs are marked on the sills and on the sides of the end floor joists. The double plate is then placed upon the tops of the studs on all four sides of the structure and the building is ready for the roof framing and the collar beams. Before the work on the roof framing is started the entire framework already erected should be inspected and all walls and partitions should be carefully lined up, plumbed, and strongly stayed by braces nailed to the floor system.

Openings.—While the roof rafters are being framed or even before, the openings for the windows and doors should be framed followed by the placing of the wall sheathing. It is usual to sheath the walls of a building before the roof boards are placed as this braces the building and gives better protection against the force of the wind.

Cornice.—The placing of the cornice follows the sheeting of the sides and is followed by the roof boards and roof covering. The window and door frames are now placed. During this period in construction the roughing in of the plumbing, the electric wiring, and similar work should be progressing. The underflooring, if not laid previous to this, may now be placed.

Plaster.—The plaster grounds should now be nailed in place and the interior wall covered with the lath and plaster. After the plaster work has been done the frames of the interior doors are placed followed by the top flooring and all interior trim such as window and door casings, baseboards, and the like. Doors are now hung and sashes fitted and the plumbing and electric fixtures installed.

MILL BUILDINGS

Heavy Frame.—Wooden mill construction is the term applied to a type of building which is very popular for manufacturing, storage, and office purposes in the United States. A structure of this type is designed with timber columns and girders of large cross-section and with floors made of heavy plank laid directly upon the girders. Mill-constructed buildings were first built in New England for textile-mill purposes and are probably still to be found there in greater numbers than elsewhere. Many of the old mills of this type well over a hundred years old are giving useful service and are still in a well-preserved state.

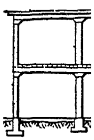


FIG. 150.—Section through wooden mill building.

A wooden mill building (Fig. 150) is admirable on account of the simplicity of its framing, the strength of its construction, and its light and spacious interior. Such a building is comparatively cheap to construct and the building operations in connection with it are simple and quickly performed.

The wooden mill building is in much favor with the fire insurance companies as the fire risk is small. The timber framing and plank floors are arranged in heavy masses with smooth, flat surfaces and consequently, there is little chance for fire to gain headway in the building. Large timbers and heavy planks burn slowly, and for this reason the wooden-mill construction is frequently termed "slow-burning construction." With its develop-

ment as a fire-resisting construction, the wooden-mill building has been subjected to many improvements and refinements in connection with fireproof partitions, stairways, and the like. The general methods of framing and manner of forming the floors in wooden-mill construction are frequently made use of in the design of buildings having brick walls.

Columns.—The columns are spaced anywhere from 8 to 11 feet in a longitudinal direction and anywhere from 16 to 25 feet transversely of the building (Fig. 151). The spacing allowable will depend entirely upon the size of timbers used for the girders

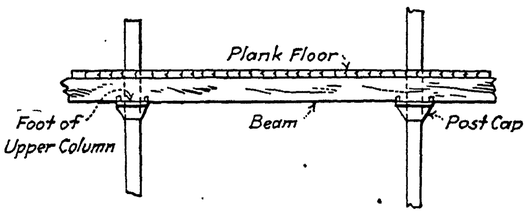


FIG. 151.—Section through mill construction floor.

and the thickness of the floor planking. In deciding upon the spacing for the columns and the sizes of floor members, the purpose for which the building is to be erected should be kept in mind and a spacing should be selected which will give sufficient working room between the columns, and at the same time permit a practical selection to be made in choosing sizes of girders and floor planking as discussed further on.

The columns should preferably be square in cross-section and not less than 8 by 8 inches. The ends should be squared at right angles to the axis of the column and bored with bolt holes and otherwise prepared to receive the iron cap and base. The four corners of the column should be chamfered to remove the sharp edges. This improves the appearance of the column and adds something to its fire-resisting qualities.

The bases of the columns are designed usually to rest upon concrete piers. Where there is no basement, the interior columns rest upon isolated piers, as in Fig. 150. The wall columns may also be arranged to rest upon piers in similar fashion but are more frequently placed upon a light wall which is enlarged at the columns and is designed to support the light wooden framing for the side walls along its length. Where there is a basement, the interior columns may be carried down to a pier, the top of which is 1 or 2 inches above the top of the basement floor. The columns

are made in lengths of one story and are provided with iron caps and bases.

Caps.—The foot of the column of each upper story should rest directly upon the cap of the column below (Fig. 151). This cap may be a casting or may be made of rolled-steel shapes. In either case it should be bolted to the top of the column and should provide ample bearing for the girders and the foot of the column above. The girders should be arranged to fit into the sides of the cap and should be held securely in place by lugs on the casting or by bolts extending through the girders.

Bases.—All columns resting upon the foundations should set in a cast-iron or steel base. The base should be bolted to the foundation with two foundation bolts but need not be bolted to the column.

Girders.—The simplest type of mill-constructed building has girders running crosswise of the building, the floor planks being laid flat upon the tops of the girders. No girder should be allowed which is less than 8 inches on a side. The spacing of the girders and, consequently, the spacing of the column in a longitudinal direction, is then dependent upon the allowable span of the floor plank. With ordinary floor loads 3-inch plank will serve for an 8-foot spacing between girders and 4-inch plank for a 10-foot spacing. Greater spacing may be obtained by using what is known as a "laminated floor" made of planks or scantling laid on edge. A laminated floor will permit a girder spacing of from 12 to 18 feet.

It is frequently desirable to maintain a wide spacing of columns and at the same time use 2- or 3-inch plank for flooring. In such a case longitudinal girders may be used with floor beams framing into them. In this manner with a spacing of 4 feet for the beams, 2-inch plank may be used or a spacing of 8 feet with 3-inch plank. All girders should be surfaced on all four sides and lower edges may be chamfered.

The ends of adjacent girders at the columns should be tied together by a fishplate bolted to each girder with two bolts. When floor beams are supported by longitudinal girders, the ends of the former may rest upon the tops of the girders or upon the top of a timber bolted to the side of them.

Flooring.—The flooring of a mill-constructed building is ordinarily constructed of plank not over 9 inches in width and not less than two bays in length. When 2-inch planks are used they

should be tongued and grooved. Three-inch plank may be tongued and grooved or splined; 4-inch plank should be splined. The splines should be of hardwood about ¾ by 1½ inches. All planks should be surfaced on all sides.

To protect the floors below, the plank may be covered with at least one layer of rosin-sized building paper or waterproofed felt and then with a wearing surface of hardwood flooring. Waterproofed felt is preferable to rosin-sized paper for this purpose, as the former forms a better cushioning against sounds and prevents any water from leaking through when the floors are being washed.

The top floor is usually of ⅞-inch maple which is tongued and grooved along the edges and the ends. A top flooring of ⅞-inch spruce is often used in cheap construction. Square-edged flooring is often used on account of the ease with which boards may be taken up and repairs made. As such boards are nailed through, the nails are likely to prove unsightly and eventually the boards will become worn and have an uneven surface.

The following table represents approximately the relative proportions of story heights to width of building in good practice:

h of Building	Floor to Floor
25	12
50	13
75	14
100	15

Partitions.—Partitions in mill buildings may consist of 2-inch plank set vertically and covered with plaster laid on metal lath on both sides or of a 2-inch solid partition of cement plaster on metal lath with iron studs. A desirable partition may be made of gypsum blocks.

Gypsum-block partitions make one of the lightest practical partitions known and compare favorably in cost with other fireproof partitions. Gypsum blocks are made of plaster of paris mixed with other materials. They are made from 2 to 8 inches thick and may be cut with a saw to fit around openings and corners. They hold nails reasonably well and are intended to be plastered on both sides. The edges of the blocks are grooved to furnish a key to the plaster cementing adjacent blocks. The blocks should be laid in regular horizontal courses breaking vertical joints. They should be laid in a mortar made in the

proportions of 100 pounds of gypsum cement mixed with 3 cubic feet of sand. In forming openings wooden door bucks are necessary.

Outside Walls.—The outside walls of mill buildings of this type consist chiefly of windows. The window frames often fill

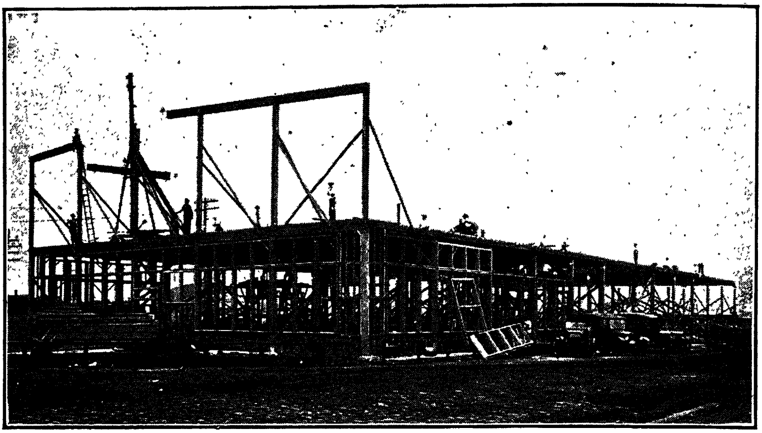


FIG. 152.—Wooden mill construction.

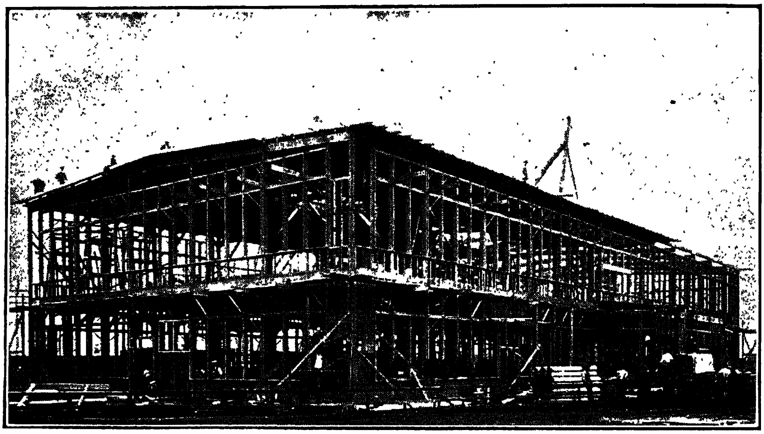


FIG. 153.—Wooden mill construction.

the entire distance between the posts leaving only small areas to be filled in below the windows and in front of the posts. These remaining spaces may be filled with planks set vertically and covered with metal lath and plaster on both sides. Another way of filling these spaces is by erecting studding and covering the

inside and outside with metal lath and plaster. Figures 152 and 153 (photographs) show views of a building in the course of erection with side walls constructed of studding and metal lath and plaster. The details of construction are shown clearly in the illustrations.

The building pictured is framed with transverse floor beams supported by longitudinal girders. The roof construction also

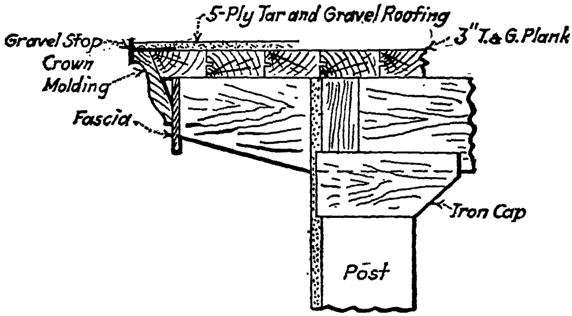


FIG. 154.—Eave detail.

departs from standard construction by the use of purlins resting on transverse girders. The details of window and door openings do not vary greatly from those in light-frame construction, except

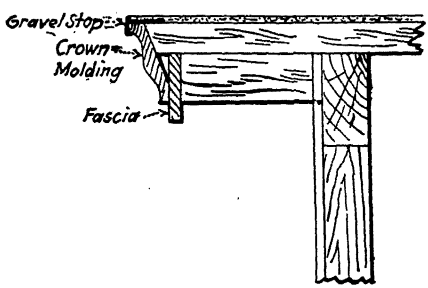


FIG. 155.—Gable detail.

that deeper frames are required by the studding which is 6 inches wide. This is necessitated by the height from floor to floor.

Roofs.—The roof of a mill building is usually designed to be almost flat, a pitch of ½ inch to 1 foot being sufficient. The roof plank should span two bays. Three-inch planks commonly employed for roof sheeting, are suitable for a span of 10 feet where they carry such snow loads as occur in New England. Tar-and-gravel roofing is almost universally employed as roof

covering. A standard way of making such a roof covering is described elsewhere in this book.

Cornices.—Wooden mill buildings are built usually with an open cornice. Gutters are unnecessary and are not used. The same principles control the arrangement of the members of a cornice on a mill building as obtain in the cornice of a building of light-frame construction. Figure 154 represents a section through the cornice at the eaves of a mill building and Fig. 155 a section through the cornice at the gable end.

ERECTION OF MILL BUILDINGS

Lumber.—As soon as the lumber for columns, beams, and girders is delivered at the site of the building, every timber should be inspected for defects. Each stick should be plainly marked on the ends with paint in a suitable manner to indicate whether it has been accepted or rejected. A licensed lumber inspector may be profitably engaged for this work if the quantity of lumber warrants it.

Posts.—As soon as the concrete foundations have been finished, preparations may be made to erect the first-story posts. As some of the concrete piers will usually prove to be somewhat out of level due to unequal settlement of the wet concrete in the forms, and as the posts will be all cut to the same length, it is necessary to arrange to set the bottoms of the posts at the same elevation or the upper floors will be out of level. To accomplish this, each iron base plate should be set in place on the pier in a bed of cement mortar of sufficient thickness to bring the foot of the post to the correct elevation. The iron base should be brought accurately to line and set exactly level on the pier.

Small steel wedges inserted between the base plate and the top of the concrete pier may be utilized in leveling the plate and holding it in position until the mortar has set. The mortar used for bedding the bases should be made in the proportions of one part of cement to two parts of sand. Sufficient time should be permitted to elapse for the cement mortar to harden before the erection of the posts is started. The iron post caps are usually bolted to the tops of the posts previous to erection of the latter.

Post and Girders.—The heavy timber posts and girders can be most conveniently erected by means of the pole derrick, or "dutchman" as it is often called. (The pole derrick is described in the chapter of this book dealing with Erection and Rigging.)

The pole derrick may be rigged in any of the ways described. The most convenient arrangement is a derrick with a small winch bolted to the pole. A sheave wheel should be inserted in the top of the pole over which the rope may pass in traveling from the tackle blocks to the winch. Pole derricks rigged with a small steel hoisting cable may be purchased which are already rigged for this and similar work from contracting supply companies. An ordinary gin pole can also be used for setting posts and girders, but the manipulation of guy lines and the shifting of the gin pole requires considerable time and labor.

Progress.—The operation of erecting should begin at one end of the building, starting first by setting all the columns across the end of the building and following with the girders which rest

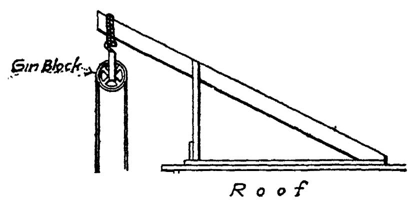


FIG. 156.—Gin-block support.

upon the columns. The pole derrick is then moved backward to the next line of columns and the operation is repeated. If there are any intermediate floor beams supported on the girders, they should all be erected so that the framing of the one bay is completed before the derrick is moved into the next bay.

When a post has been erected on its iron base, it should be carefully plumbed and stayed in both directions. After all the posts in a line have been plumbed and stayed, the girders may be set, or each girder may be set as soon as the columns supporting it have been erected. The operation of setting a girder is clearly illustrated in Fig. 152 (photograph).

Plumbing.—After the framing for three bays has been completed, the plumbness of the posts should be carefully checked and the laying of the plank floor may be started. If splined plank are to be used, the splines should be nailed in the grooves of the plank preparatory to laying them. The ends of all girders and beams should be sized to the same height so that when in place they will all be flush on top. A crosscut machine saw will

be found convenient and economical for cutting the flooring to lengths on this work.

Materials.—When work is to proceed on the upper floors of the building, all material will have to be passed up by hand or hoisted to the upper floor level. A contrivance well adapted to this hoisting is shown in Fig. 156. The brace on one side should be omitted so that materials can be pulled in at the landing without any interference from braces. It may be rigged with a tackle for heavy loads or with a sheave wheel of large diameter for light loads.

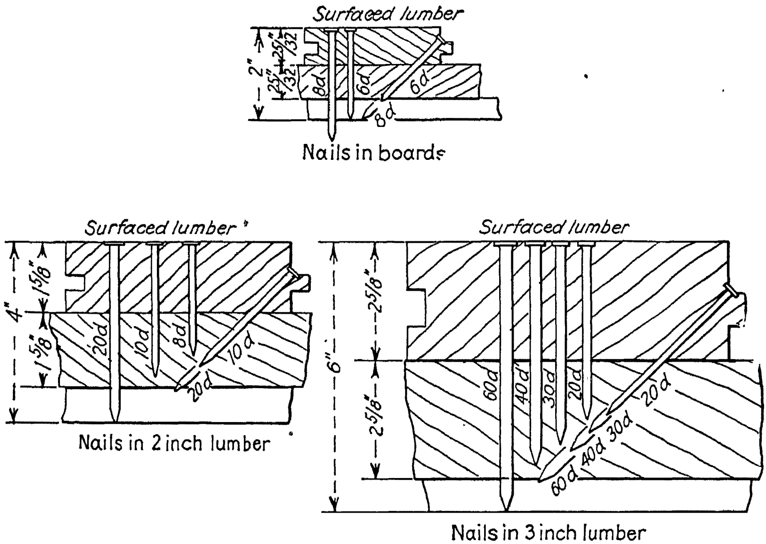


Fig. 157.—Length of nails.

Ground Floor.—If there is no basement to the building, the work on the ground floor can proceed at any time either before or after the erection of the first-story posts. If the ground-floor planks are to be nailed to wooden sleepers, the sleepers should be laid with their tops at the same grade. They may be held securely in the desired position by nailing them to stakes driven into the ground about 4 feet apart. The cinder fill or concrete fill, as the case may be, is then spread and leveled off even with the top of the sleepers.

The manner of placing windows and doors is the same as for buildings of light-frame construction. The top flooring which is

usually of maple should not be laid until all the rough work has been completed. The floor should be covered with building paper to protect it from becoming spattered with paint or marked by workmen walking over it.

NAILS

Lengths of Nails.—The length of nails used must be suited to the thickness of the lumber. The relation of different sizes

TABLE 6.—QUANTITIES OF NAILS

Material	Quantity	Pounds	Size	Kind
Joists and sills........	1000 b. m.	25	20d	Common
Studding............	1000 b. m.	15	10d	Common
Rafters..............	1000 b. m.	15	10d	Common
Sheathing, shiplap, novelty siding......	1000 b. m.	20	8d	Common
Shingling............	1000 shingles	6	4d	Common
Bevel siding..........	1000 b. m.	20	6d	Common
Flooring, pine........	1000 b. m.	30	8d	Common
Flooring, hardwood...	1000 b. m.	30	6d	Common
Baseboard...........	1000 b. m.	15	8d	Finish
Window trim.........	One side	1	8d	Finish
Door trim...........	One side	1	8d	Finish
Lath................	1000 lath	10	3d	Common, fine

of nails to various thicknesses of lumber is shown in Fig. 157. The nails are represented as though driven through two thicknesses of surfaced yellow pine lumber. The thickness of two layers of lumber of full nominal thickness is also represented. The standard thickness for yellow pine boards, surfaced on both sides, is $^{25}\!/_{32}$ inch. The standard thickness for 2-inch lumber surfaced on two sides is $1\frac{5}{8}$ inches. The standard thickness for 3-inch lumber surfaced on two sides is $2\frac{5}{8}$ inches. Different lengths of nails may be required for through nailing and for toe nailing.

Table 6 lists different sizes of nails and approximate quantities of the different sizes which ordinarily are required with the different sizes and classes of lumber.

Table 7 lists the various sizes of nails, with the lengths of each expressed in inches and approximately the number of nails to the pound for each size of nail.

TABLE 7.—LENGTH AND NUMBER OF WIRE NAILS[1] TO THE POUND

Size	Length, inches	Common	Casing	Finish	Clinch	Fence	Fine	Shingle
2d	1	900	. . .	. . .	. . .	. . .	1440	
3d	1¼	615	. . .	. . .	. . .	. . .	810	568
4d	1½	322	473	584	. . .	. . .	. . .	250
5d	1¾	254						
6d	2	200	180	300	157	114		
7d	2¼	154						
8d	2½	106	112	190	99	74		
9d	2¾	85						
10d	3	74	90	134	69	42		
12d	3¼	57						
16d	3½	46						
20d	4	29						
30d	4½	23						
40d	5	17						
50d	5½	14						
60d	6	11						

[1] A keg of nails weighs 100 pounds.

CHAPTER VI

BRICK AND STONE CONSTRUCTION

Brick.—Brick is a popular material for the construction of building walls. Its claims upon the favor of a prospective builder are many. Among them are the economy and the appearance of the brick walls as well as their strength. Brick masonry affords protection from dampness and extreme temperatures of heat and cold. The simplicity of the construction equipment required is a highly commendable feature. The facility with which deliveries of materials may usually be obtained is also in its favor.

Bricks.—Bricks are solid blocks of burned clay. The different varieties of brick are occasioned by different processes of manufacture that produce differences in the surface texture and in the color. Bricks are commonly made from clay, although there are bricks on the market which are made from shale, cement, and other materials. Brick-making material is usually obtained from surface beds of clay, which is dug out and pressed into shape in molds. The molded blocks of clay are then placed in piles and burned for several days in kilns by exposure to a heat of about 2000°.

The differences in the manufacture of brick lie largely in the methods of molding and shaping the blocks. Common brick have the natural surface left by the impression of the molds. Face brick are those which have been treated so that their surfaces show special effects in texture and color. Pressed brick are made by pressing practically dry clay into molds under enormous pressure which results in giving the brick a fine smooth surface and true angles and corners. The bricks are then set in the kilns and burned.

Previously, common brick were manufactured in various sizes, the three dimensions varying according to the standards favored by individual brick manufacturers. At a recent meeting of the Common Brick Manufacturers of the United States,

it was agreed upon to standardize the size of all common brick to 8 by 2¼ by 3¾ inches.

Manufacture.—Bricks may be made by the soft-mud process or by the stiff-mud process. The soft mud-bricks are made by pressing wet clay into molds. The stiff mud bricks are made by forcing stiff clay through a rectangular die in the form of a continuous bar and cutting it into blocks. There are two varieties of soft-mud bricks. These are known as sand- and water-struck bricks.

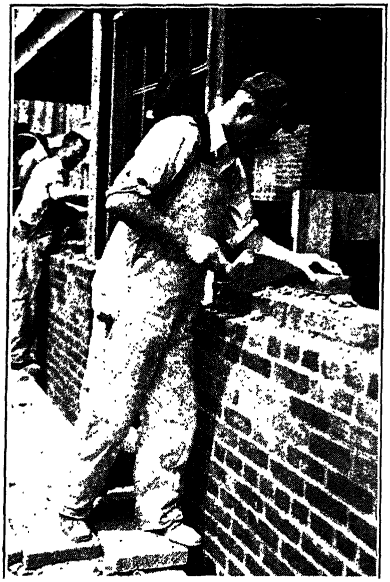


Fig. 158.—Building a lead.

The sand-struck brick, which is the common brick usually employed for inexpensive work, derives its name from the method used to prevent the wet clay from sticking to the molds. The mold is dashed with sand and filled with clay, the excess clay being struck from the mold. The sand becomes embedded and is burned fast to the rough and unglazed surface of the brick. This sand is always visible on sand-struck brick.

In making water-struck brick, the mold is moistened with water to prevent the clay from adhering to it. This gives rise to the term "water struck." Water-struck bricks are more expensive and less commonly used than the sand-struck bricks. The water marks may usually be distinguished on their surface.

Stiff-mud or wire-cut bricks, as they are more frequently called, are not molded like the soft-mud bricks, but are formed by cutting a bar of stiff mud with wire cutters into blocks of the desired size. The resulting bricks are termed either "side-cut" or "end-cut" bricks, according to whether the sides or ends are formed by the cutting process. The stiff-mud bricks are dried and burned in the same manner as the soft-mud bricks. Stiff-mud bricks are used almost entirely as face bricks.

Bricklaying.—To facilitate removal from the molds, soft-mud bricks are made with one side of greater width than the other

(Fig. 159). The wider of the two sides is known as the top of the brick and the narrower side as the bottom of the brick. This difference may be seen if a brick is examined closely and may be readily distinguished with a little practice by the feeling of it when held in the hand. There is also a toe and heel to a common brick. The toe end is rectangular, the heel end is slightly curved into a bull nose at one edge, as shown in Fig. 159. A bricklayer must be careful in laying headers not to have the curved heel end outward on the face of the wall. Bricks are usually marked with letters giving the name of the brick or the name of the manufacturers. The letters are always placed on the bottom of the bricks. The top side of a brick is usually well shaped and the edges are straight and true; the bottom is not so well formed. Bricks are always laid with this wide or top side up, as indicated in Fig. 159. If laid indiscriminately with either the wide or narrow side upmost the face of the wall would appear as in the figure.

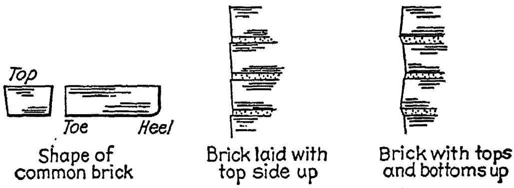


FIG. 159.—Shape of common bricks.

A wire cut face brick is rectangular in shape. There is no toe and heel as on a common brick. A face brick, however, often has a front and a back. The front is usually perfect in shape, texture, and color, but the back is marked by the machinery of manufacture with several unsightly marks.

Leads.—In building a wall the corners of the building and, at times, one or more intermediate points are carried up a few courses above the main portion of the brickwork as a guide to the laying of the brick in the remainder of the wall. These advance points are termed "leads" and are laid by the more experienced men of the gang. The corners require the most careful work; they must be carried up plumb on both sides. This is done with the aid of the mason's level.

Supervision.—In supervising the laying of the brickwork, the sharp edge of the corners should be frequently sighted for alignment. It is also well to watch the general surface for humps and

bulges, and the edges of finished jambs sighted occasionally for alignment. The mortar mixing should be watched for the color of the mortar.

A common fault in bricklaying is a variation in the thickness of joints between courses. A difference in thickness of joint is easily discernible and will spoil the appearance of the work. Another defect often seen is a dip in a course. This results from laying the bricks to a sagging line.

FIG. 160.—Setting terra-cotta block.

Laying Brick.—To keep the courses of brick level along the wall and the surface in alignment, a line is stretched from one lead to another. The line should be supported at the intermediate leads in such a manner that the line will mark the correct position for the top edges of the course to be laid. The brick are laid so that the top of each brick comes about ⅛ inch from the line. No brick should be allowed to touch the line, as it is likely to lead the wall out of plumb. As each course of brick is laid, the line is raised for the succeeding course.

In laying the face brick, as the top edge of each brick is brought to the line, the brick is given a slight roll so that the lower edge sets slightly back from the top edge. A section through the wall appears, as in Fig. 159.

A stiff mortar is preferable for bricklaying. A soft or wet mortar is likely to cause the bricks to slip out of position. With a stiff mortar, there is less tendency to smear the surface of the face brick with mortar. On a good job of bricklaying, there should not be any messing of the face brick with mortar. The bricks should be laid neatly and the mortar should be kept off the face of the bricks. The mortar should appear only in the joints. The edges and corners of each brick should not be

hidden by mortar anywhere and there should not be any cracks visible between bricks and mortar.

A bricklayer when laying face bricks and working backward along the wall butters each face brick with mortar with his trowel and shoves the buttered brick forward against the brick previously laid. When working forward along the wall, he butters the end of the brick in the wall instead and lays the new brick against it.

The position of the trowel when buttering a brick is such that an indentation is formed between brick and mortar when a

FIG. 161.—Finishing a parapet wall.

brick is laid. This indentation closely resembles a crack between brick and mortar and is known as a trowel mark. It can be removed only by careful jointing work with the trowel or jointing tool. A full end joint of mortar may be buttered on the end of a brick by applying the trowel to the bottom edge at the end of the brick rather than to the face edge.

Building a Wall.—When building a brick wall, a bricklayer lays the bricks in the tier farthest from him several courses in advance of the tiers nearest the scaffold. If the scaffold is inside the building, the outside brick are laid first; if the scaffold is outside the building, the inside brick are laid first. This is the most convenient manner of procedure, as it is not necessary then for the bricklayer to reach over the higher tiers of brick to lay the brick farther away, and it avoids the possibility of any bricks in the

highest tier being knocked over by the bricklayer's body in reaching over the wall.

Bonds.—The strength of a brick wall is attained by arranging the bricks so that they overlap and tie the various layers together in such a manner that they are able to resist any outside forces tending to destroy it. Two methods of bonding are in popular use in the United States, the American or common bond and the

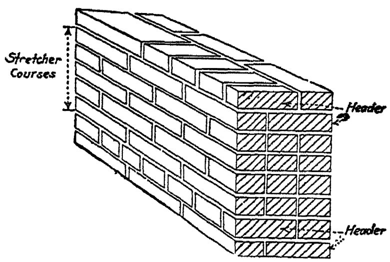


FIG. 162.—Section showing headers. Common bond.

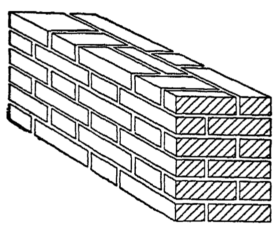


FIG. 163.—Flemish bond.

Flemish bond. Before discussing bonds, a few definitions will prove helpful.

A stretcher is a brick laid lengthwise of a wall and binds the wall together in that direction.

A header is a brick laid crosswise of the wall and binds the wall together in a transverse direction.

A rowlock brick is a header laid on edge.

A bull stretcher is a stretcher laid on edge.

A soldier brick is a brick laid with long sides vertical.

Common Bond.—Common bond is formed by five courses, all bricks laid stretchers, followed by a sixth course all brick laid headers (Fig. 162). This bond is used in laying the greater part of all brickwork done in the United States. It is the least costly in regard to labor and may be used either for walls with exposed on unexposed surfaces. In 12-inch walls, which is the thickness ordinarily employed for one- or two-story structures, the header courses are laid with brick arranged as in Fig. 162. In this case the headers showing on either side of the wall are placed so as to overlap at the center of the wall.

Flemish Bond.—Flemish bond may be utilized where a very artistic wall surface is desired. While it costs more to lay than common bond, it presents a much more attractive surface and is

very effective when used with raked joints, as shown in Fig. 163. Flemish bond consists of alternate headers and stretchers in the same course, the headers being spaced to come directly over the center of the stretcher below it. To break joints properly every course of brick must start at the corners with a "three-quarter" brick. A number of 2-inch splits are needed around openings.

Joints.—The mortar in the horizontal joints provides an even bed for supporting the bricks above it; the mortar in the vertical joints serves mainly to bind the bricks and prevents the entrance of the weather. In bricklaying, it is the common practice to "butter" the ends of the face brick and to lay them in a full bed of mortar shoving them endwise into place to fill the end joints completely. The bricks in the backing are commonly laid in a full bed of mortar. The vertical longitudinal joints are slushed full of mortar with a trowel. The vertical joints in the backing may also be grouted with thin mortar. In ordinary bricklaying work, the joints in the interior of the wall are not filled with mortar in every portion of the wall. It is customary on cheap contract work to slush all the joints full every fifth course. The filling is done when the header course is laid.

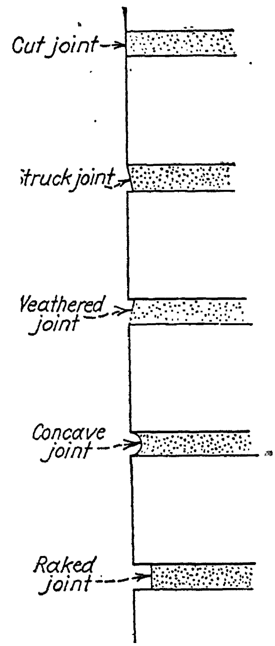


FIG. 164.—Brick joints.

In grouted walls, the bricks on both faces of the walls are laid with shoved joints in a full bed of mortar as before. The bricks in the middle of the wall are laid in a full bed of mortar likewise, but the vertical joints are filled with very wet mortar poured from a dipper.

With lime mortar, brick joints should not overrun $3/8$ inch in thickness. With cement-lime mortar, the joints may be made much larger with safety on account of the extra strength gained by the use of the cement.

For an attractive wall surface, the joints between bricks should be of such a thickness that each individual brick can be plainly

seen. In ordinary brickwork, joints of about ½ inch are commonly used. The joints may be finished in the manner most suitable to the work. The most popular joints are the flush cut, the struck, raked, and concave.

The cut joint (Fig. 164) is suitable for concealed surfaces or walls that are to be plastered. It is formed by simply cutting off the excess mortar with the edge of the trowel.

The struck joint (Fig. 164) is the cheapest and most easily formed joint. It is very commonly used for the exterior, exposed surface of walls of industrial buildings, as well as for the interior surfaces which are not intended to be plastered. It is formed by

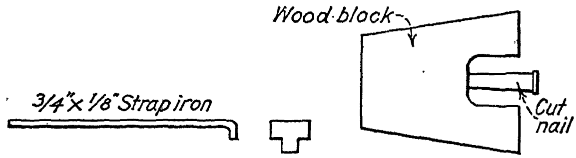


FIG. 165.—Tools for raking joints

cutting away the excess mortar, in the same manner as when a cut joint is formed, and finishing the joint with the point of the trowel.

A raked joint is formed by laying the bricks with a flush cut joint. The mortar is allowed to set and stiffen for an hour or two and then is raked out with a tool as shown in Fig. 165. The joint may be raked out to any depth from ⅛ to ½ inch depending upon the appearance desired. If a rough finish is desired on the mortar, the joint can be left in the condition in which it is when raked out. A very rough finish can be secured by raking with the end of a stick.

If a smooth and hard packed joint is desired, the surface of the mortar should be rubbed and packed with a flat jointing tool. This tool is known as a slicker.

A concave joint is made by laying the brick with a flush cut joint and rubbing the joint mortar with a concave jointing tool. A piece of pipe may be used as a jointer but it leaves a dark mark on the mortar. An effective concave jointer can be made from pieces of a hickory sledge handle.

Mortars.—For many years all bricks were laid in pure lime mortar. Later, mortar made with natural cement came into use. With the advent of cheap portland cement, the mortars made with lime and with natural cement were superseded by portland-cement mortars containing various proportions of lime. At the

present time, the use of pure lime mortar for ordinary bricklaying is regarded as obsolete. Almost all brick work is laid with a portland-cement mortar or a cement-lime mortar, both of which will be discussed further on.

Sand.—The sand used in making mortar for bricklaying should be fine. Sand which is ideal for making concrete is too coarse for a good bricklaying mortar where thin joints are desired. Where the brick are to be laid with thick joints, a coarse-grained sand is preferable.

All sand used for making mortar should be screened; otherwise the bricklayers would be compelled to spend a large portion of their time picking gravel out of the mortar when laying the bricks. The screen commonly used has a mesh which is long in a vertical direction and narrow in a horizontal direction. This permits faster screening than a square mesh. The mesh for a sand screen should have three or four meshes to the inch.

Portland-cement Mortar.—A mortar made of portland cement and sand is not plastic. It is very hard to lay bricks in a pure cement mortar, as such a mortar is inert and granular and quickly loses its moisture by absorption by the bricks. A certain proportion of lime is usually added to it to make the mortar plastic. The mortar, which at the present time is universally known as portland-cement mortar, is made of portland cement mixed with not over 10 per cent, measured by weight, of dry hydrated lime or its equivalent of lime putty. This is the same as one-fourth the quantity by volume. The mortar is further proportioned by mixing one part by volume of the cement-lime mixture with three parts of sand. Portland-cement mortar is used in masonry which is to support heavy loads and in foundations and other work in damp, exposed locations.

Cement-lime Mortar.—A cement-lime mortar is plastic and works well with the trowel, and its use results in brickwork of high strength. It is similar to the portland-cement mortar just described except that the proportion of the quantity of lime to that of cement is increased. A good bricklaying cement-lime mortar may consist of equal quantities, in volume, of cement and lime putty or hydrated lime. The sand should be mixed with the cement and lime in the proportions of three parts of sand to each part of the cement-lime mixture. When lump lime is employed, an equal amount of lime putty may be substituted for the hydrated lime.

Making Mortar.—In making cement mortar with dry, hydrated lime, the cement and hydrated lime should be mixed together until the lime is thoroughly and uniformly distributed through the cement. The cement is first emptied out of the bags on a mixing board and the correct proportion of lime is placed on top of it. The two materials are then thoroughly mixed dry with a shovel or a rake. The correct quantity of sand is then placed on another portion of the mixing board and the cement-lime mixture is added to it, the whole mass being turned with a shovel and manipulated with a rake until of an even color. Water is then added and the mortar is turned with a shovel and a hoe until thoroughly mixed.

Various departures from the foregoing procedure are possible. In any case the mortar should be sufficiently lean when handled on a trowel to leave the blade clean when spread on the wall. If made too fat, it will stick to the trowel. The mortar mixer is guided in this matter by the behavior of the mortar when in contact with the blade of the mixing hoe.

Lime Mortar.—When lump lime is employed for making mortar, it should be slaked with water in a watertight box or a basin formed by the sand of the batch. In slaking lump lime care should be exercised not to add either too little or too great a quantity of water to the lime. Too small a quantity of water may result in "burning" the lime. Too great a quantity of water may result in "drowning" it. A sufficient quantity of water should be added slowly to prevent any too violent generation of steam. The white lime paste resulting from the slaking process is known as lime putty.

As soon as the slaking process is complete, the sand is mixed with the lime putty, one part of lime paste to three of sand, and the mix is shoveled into a heap to cure for several days, preferably a week or more. The older the lime mortar, the better the resultant work.

When the mortar is taken from the curing pile to be used, it should be tempered; that is, softened by adding water and working with a hoe or shovel until all the white spots in it disappear. The white spots are portions of unslaked lime which later would swell and slake in the completed work. On ordinary small work, however, lime mortar is often mixed for bricklaying as soon as the lime putty has become cool.

The equipment ordinarily required for making mortar for bricklaying is as follows: a sand screen, 72 by 28 inches; a mortar box about 4½ by 9 by 1 foot deep; a platform for the mortar pile; a water barrel and hose; a few pails; and a hoe and a shovel for mixing the mortar.

Brick Walls.—Brick walls laid in common bond vary in width by multiples of about 4 inches of thickness depending upon the width of the brick and the thickness of the vertical joints. Walls of one tier of brick in thickness are seldom used except for partitions in residences or other very light constructions. Walls of two tiers in thickness are ordinarily used for partition walls, but may be used for bearing walls in residences. For bearing walls or walls supporting loads in industrial buildings, a thickness of three brick is the minimum thickness allowable.

Size.—The standard size of a common brick is 8 by 2¼ by 3¾ inches; therefore, a wall two bricks in thickness with a ½-inch vertical joint between the bricks should measure 8 inches, a wall three brick in thickness will likewise measure 12¼ inches, and one four brick in thickness 16½ inches. As a matter of fact, these dimensions may easily be made to vary by increasing or decreasing the thickness of the vertical joints between each tier of brick. Faster progress may be made with wide joints than with close joints, so the tendency is for walls to overrun rather than underrun the thicknesses stated. A wall two tiers of brick in thickness, however, is limited to 8 inches, the length of a brick header.

Color.—If the bricks vary too greatly in color, they may be culled to separate the dark bricks from the lighter ones. The dark brick being less pervious to dampness and of a more pleasing shade should be laid in the face of the wall. The dark hard-burned brick are often so irregular in shape that it is difficult to bed them properly in the mortar. The soft light-colored brick should be laid in the backing. The light brick are the most regular in color and shape and are approximately the standard size. The dark bricks are always much smaller in all dimensions than the soft-burned light bricks. It is seldom necessary for any culling for color to be done except that done by the bricklayers when laying the brick.

Pilasters.—Pilasters on the exterior or interior faces of walls are given a projection of one brick plus the width of a mortar joint. This projection is usually given as 4 inches. Corbeling of

brickwork in wall construction usually is carried to a total projection of 4 inches, this projection bringing the face of the brickwork, either supported or capped by the corbeling, out to the plane of the surface of the pilasters. As the allowable projection of each brick laid flat in a corbeling is limited to 1 inch, each corbeling will consist of four projecting brick. The corbeling at the eaves of a brick building is usually carried out (Fig. 166)

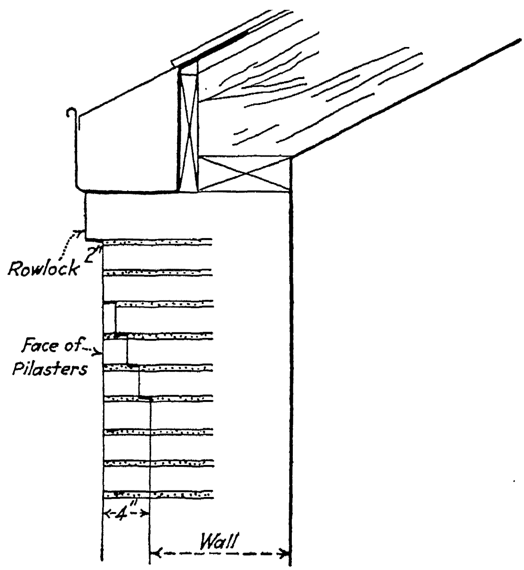


FIG. 166.—An eave detail.

beyond the face of the pilasters to support the gutter and box in the ends of the roof supports and is usually made more or less ornamental by variations in the brickwork caused by changes in the corbeling.

Foundation Walls.—The foundation walls of buildings with brick superstructures are usually made of concrete. Concrete is cheaper per cubic foot of wall than brick masonry and has greater strength and stability. Concrete is also fairly impervious to water and when necessary may be easily waterproofed with asphaltum or tar pitch and felt. In all justice to brick, however, it should be stated that a damp-proof wall can be built of paving brick laid with portland cement mortar. Paving brick, however, are more expensive than common brick.

A concrete wall should extend above the ground line and should finish in a slanting water table extending from the wall to the line of face of the pilasters. In ordinary construction the outside face of a pilaster, is carried flush with the face of the brick pilaster. In more important construction the foundation wall is made to extend 4 inches beyond the face of walls, as shown in Fig. 167, and to follow the outline of the pilasters, but extends 4 inches beyond them forming a concrete pier.

Pilasters.—Brick pilasters are located under the ends of roof trusses to strengthen the walls at those points. They are spaced at regular intervals along all bearing walls supporting beams or rafters to act as buttresses and to strengthen the wall against buckling. Pilasters also improve the appearance of a long wall by breaking up the blank surface into a series of panels, the greater part of the area of which is occupied by windows and doors. Pilasters may be made in various widths to suit the general proportions of the building and the purpose for which they are intended.

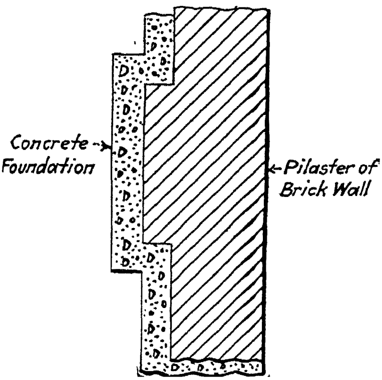


Fig. 167.—Section plan of pilaster.

Gable.—The gable of a building with brick walls is finished usually by a corbeling similar to that at the eaves, the corbeling being carried along parallel to the roof surface. Where the gable corbeling meets the eaves, it should finish against the return of the eave corbeling, as in Fig. 168.

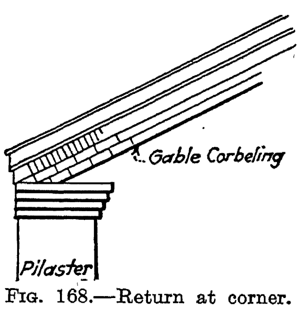


Fig. 168.—Return at corner.

Walls.—The thickness of the brick walls may be increased at the floor lines by corbeling out 4 inches to the plane of the face of the pilasters. This increase in thickness strengthens the walls, where the ends of beams are inserted, and improves the appearance of a building which otherwise would have the panels between the pilasters with a height relatively out of proportion to their width.

Where a building with brick walls is designed with a flat roof, the walls are usually extended above the roof on all sides forming what are known as "parapet walls."

Municipal ordinances often specify that they shall extend above the roof a distance of 3 feet, and this height is usually conformed to with all parapet walls. Where parapet walls are built on all sides of a building, the roof drainage is taken care of through cast-iron leader pipes within the wall lines (Fig. 169) or may be led into leader heads fastened on the outside of the

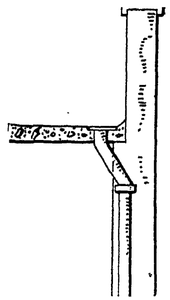


FIG. 169.—Conductor pipe inside wall.

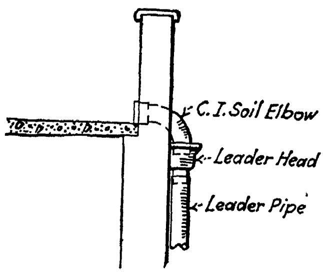


FIG. 170.—Leader outside wall.

wall (see Fig. 170). The parapet wall is often omitted on the rear of a building, however, where the appearance is not important. The drainage is then led to a gutter in the rear and down leader pipes on the outside.

The top of a parapet wall should be capped with a tile coping or a coping of stone or concrete made to extend 1 inch beyond each surface of the wall to protect the joints of the brickwork from being washed out by rain.

Supports over Openings.—The brickwork over all openings not over 5 feet wide may be conveniently supported by brick segmental arches of comparatively small rise. If the opening does not contain a door or window frame, the brickwork joints of jambs must present a neat appearance. The masonry is built up to the spring of the arch and all joints between brick along the jambs are carefully pointed. A wooden-arch center is then put in place upon which the brick arch is built. In an opening containing a door frame or a window frame, the frame is placed in position and the brickwork is laid in contact with the frames.

Where appearance is not a factor, a good rule for proportioning the rise of an arch is to allow 1 inch of rise to each foot of width of

opening. This gives an arch which is somewhat flat in appearance but is cheaply and quickly built and is suitable for relieving arches over windows and in basement walls. If the rise is made one-eighth of the span, a very well-proportioned arch will result that is suitable for the tops of windows and doors in the exterior walls.

Windows and doors for openings with segmental arches are made with segmental heads and, where the brick backing over

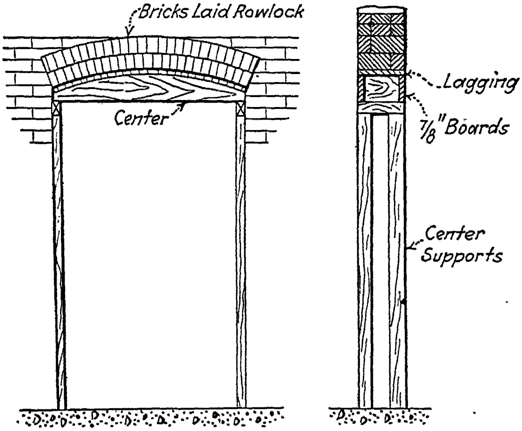


FIG. 171.—Center for brick arch.

the opening is supported by a wood lintel and relieving arch, no centering is required. The segmental head of the frame furnishes sufficient support for the face brick.

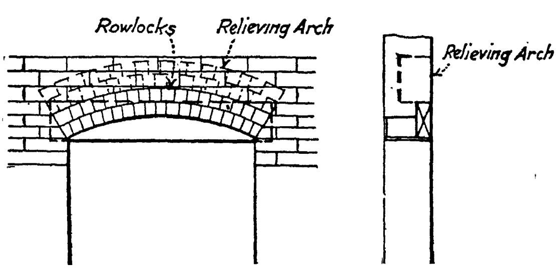


FIG. 172.—Relieving arch over wood lintel.

Where openings do not contain any frame, a centering must be made for supporting the brick arch until the mortar has had time to set. Such a center is shown in Fig. 171. Segmental arches are usually built of bricks placed on edge. These are called

"rowlocks." The bricks are usually laid in two or more rings. In a wall 8 inches thick, the brick extend through from one face of the wall to the other; in a 12-inch wall, the arch rings are made of one brick of full 8 inches in length and a half brick; the bricks adjacent in the same course are laid in reverse manner thus breaking the joints.

The backing over openings not over 3 feet wide may be carried on a wood lintel or a piece of angle iron. If the opening is 4 feet or over, a relieving arch may be built above it (Fig. 172).

Openings in brick walls may be built with a flat soffit by supporting the brickwork on steel lintels (Fig. 173). For a small opening, a 3- by 3- by ¼-inch angle iron on each face of the wall

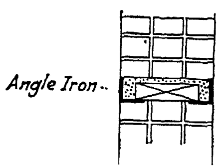


Fig. 173.—Flat soffit.

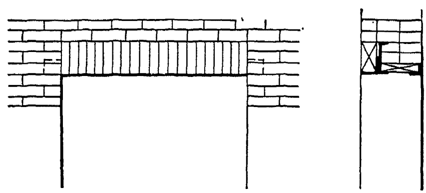


Fig. 174.—Soldier bricks.

to support the brick is sufficient. The lintels should have a bearing of 4 inches on each side of the opening and should be painted before they are put in place. The bricks in the exterior face of the wall over steel lintels are frequently laid as soldier bricks (Fig. 174).

Window Openings.—There is some difference between the details of wooden window frames intended for a brick building and those for a frame building. The sashes and the arrangements for sliding them up and down are the same. In the standard type of wooden frame designed for an opening in a brick wall, the space for the sash weights is completely boxed in, Fig. 175, and the front casing is made to project ½ inch into the brick masonry to hold the window in place. It also acts as a wind stop, blocking a continuous passage between the air inside and outside the building.

A molding called a brick molding, is secured to the frame and serves as a guide against which the brick is laid and at the same time closes the joint between frame and masonry against the passage of air. The molding, in Fig. 175, is purposely shown only in sections so that the more important points connected with setting the frame in the brick wall may be shown

more clearly. The parting strips, stop bead, stool, apron, and other details follow the usual construction for a frame building.

The window frame, shown in Fig. 175, is represented as set in an unplastered brick wall. The inside casing is usually not attached to the frame unless the window is ordered "cased" up. The depth of the box is so arranged that the inside casing will lap over the plaster on an 8-inch wall. In the case of a plastered wall, the inside casing is shipped separate from the window and, when walls are furred, an extra casing called a plaster casing may be used.

A section through the jamb and head of a window of rolled steel construction is shown in Fig. 176. It will be noticed that the plaster is returned around the brickwork of the jambs at the head and sides of the windows. In laying the brick around the windows, it is desirable to leave a space about ¼ inch wide between the brick molding and the brickwork. This space later should be filled with a calking of hemp and covered with a thick weathering coat of plastic calking material. Special calking materials can be bought that are manufactured for this purpose. They are superior to white lead, as they do not become hard.

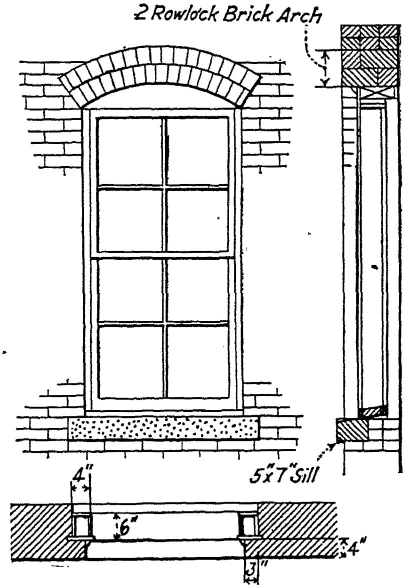


Fig. 175.—Window in brick wall.

Steel Sashes.—For the standard structural details connected with a pivoted steel sash set in a brick masonry wall, see the section dealing with Pivoted Steel Sash.

Door Opening.—The opening for a door in a brick wall differs from that for a window in that the jambs of the door opening are straight, clear through the depth of the opening. Figure 177 represents horizontal and vertical cross-sections through a doorway showing the position and the shape of the wooden jambs in an unplastered brick wall and the details at the head of the door.

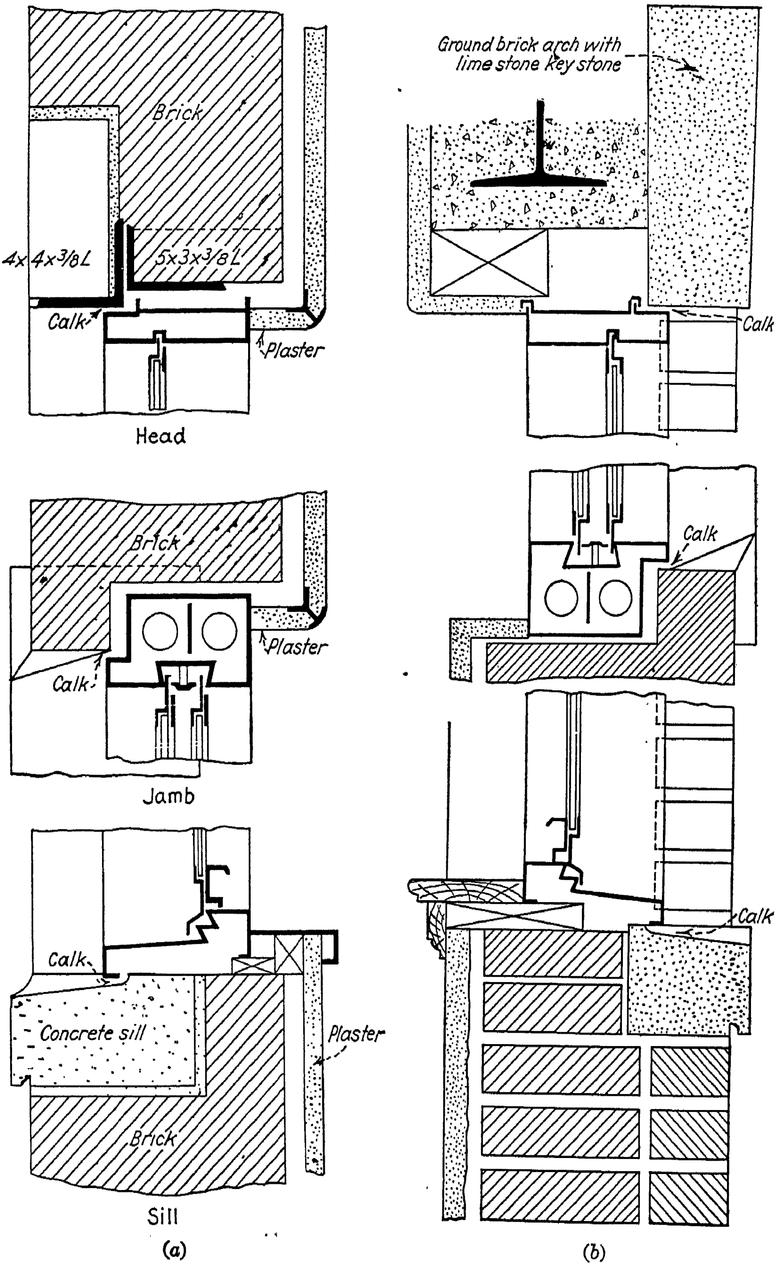


FIG. 176.—Windows of rolled-steel construction.

The door frames are set by the carpenters just in advance of the bricklaying and are plumbed and stayed by them. The jambs, usually 1¾ by 6 inches, are rabbitted for the door, as is

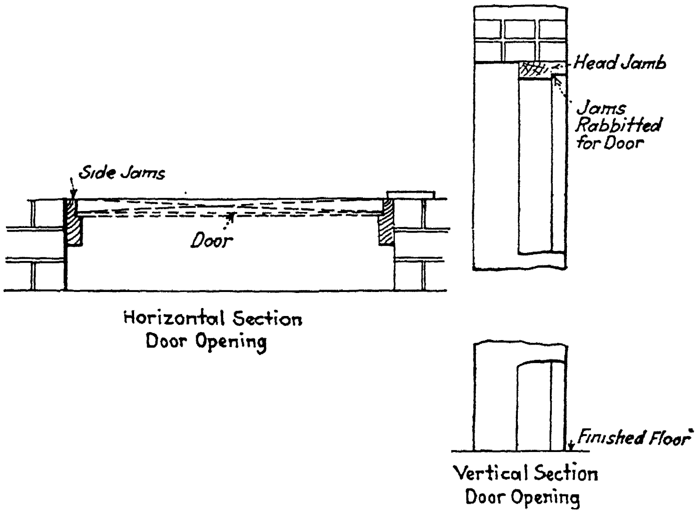


FIG. 177.—Sections through door opening.

also the head of the frame. If the door is to swing inward, the frame should be set so that the rabbited portion of the jamb is turned toward the inside of the wall; if the door is to open outward, the frame should be set in the reverse position so that the rabbited portion is toward the outside of the wall. The edges of the jambs should be set flush with the surface of the brickwork in an unplastered wall so that the casings may be nailed to them and cover the joint between the jamb and the brickwork. In a plastered wall, the edge of the jamb should be set flush with the surface of the plaster in a corresponding fashion.

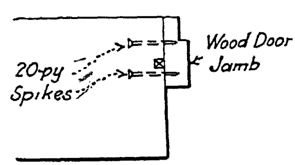


FIG. 178.—Detail of door jambs.

The jars and shocks occasioned by opening and closing a door tend to loosen the frame from the wall unless it is attached solidly to the brickwork. The frame may be held in place by wooden blocks nailed to the back of the frame which become incased in the masonry as the brick are laid up against the frame.

Probably the most convenient and satisfactory way to secure the jambs to the brickwork is by means of large nails driven in pairs into the back of the wooden door jamb (see Fig. 178). The pairs of nails should be spaced about 11 inches apart vertically which means four courses of brick in ordinary work. The nails are driven into the frame just above a course of brick as

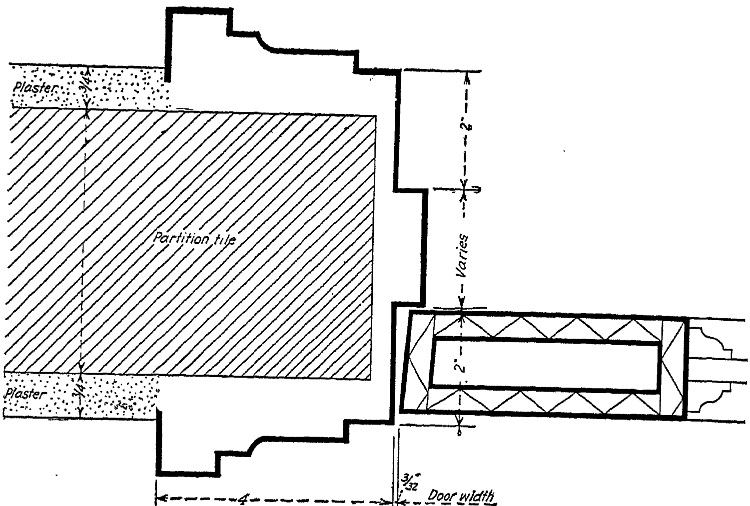


FIG. 179.—Section through steel door and buck.

the bricklaying progresses. This locates them in the mortar of the horizontal joints. It is well, also, to nail a ¾- by ¾-inch strip of wood vertically to the back of the jamb to act as a windbreak. The wood strip should be so placed on the frame that it will lie in one of the vertical joints between the tiers of brick. The nails and the wind strip are shown in Fig. 178.

INTERIOR FRAMING

Joists.—To prevent the brick walls from spreading outward where they support wooden floor joists, the ends of the latter should be equipped with iron anchors which should be shaped to bed securely into the brick masonry. Two varieties of anchor are shown in Figs. 181. The brick walls paralleling the wooden joists should be prevented from spreading outward in a similar manner, the anchor in such cases being embedded in the

wall at one end and extending across the tops of at least three joists to which it should be securely spiked (see Fig. 182).

The ends of all wooden joists which are embedded in brick walls should be cut on a bevel so that (Fig. 182), in case of fire, should the joists become burned through, the weight of the falling joists will not pull the walls down.

When the thickness of the brick walls change at each story, the change in thickness may be made to take place at the level of the tops of the joists (Fig. 182). This serves as a fire-stop.

FIG. 180.—Steel door buck in position.

Wooden floor joists should be given a bearing of at least 4 inches and the courses of brickwork should be kept level at the bottom of the joists. The latter should be carefully sized so that it will not be necessary to wedge up any joists to the correct elevation by chips of slate or wooden wedges.

Steel Beams.—Where the ends of steel floor beams are supported on a brick wall, the wall should be held against spreading by anchors similar to those used with wooden joists. The simplest form of anchor for use with steel beams is shown in Fig. 183.

The load supported by a steel beam is such that a very heavy pressure is often brought upon the masonry on which the end of the beam rests. This pressure often will exceed the pressure which can be safely resisted by the brick masonry. Thick steel or cast-iron bearing plates should be placed in the walls to support the ends of the beams. The bearing plates should extend over sufficient area to reduce the pressure per square inch to less than the allowable safe pressure and at the same time be thick enough to resist probable bending stresses. Steel beams should

be given a bearing of at least 4 inches, 6 inches or more being preferable for the larger-sized beams.

Floor Systems.—The floor systems in use in construction of buildings with brick walls may conform to the usual designs in

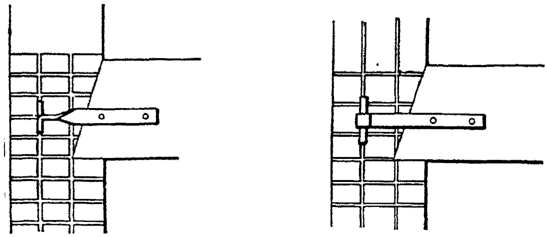
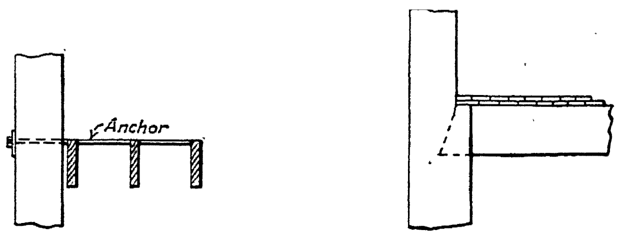


FIG. 181.—Wall anchors.

use with wooden joists in light-frame construction or may follow those used in framing and flooring in wooden mill construction.



Wall anchor. Change in wall thickness.

FIG. 182.—Wooden beams at brick wall.

Where steel beams are used, the flooring will usually consist of a concrete slab reinforced by either steel rods or some variety of steel mesh.

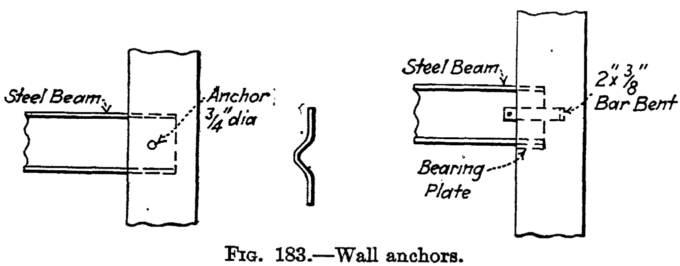


FIG. 183.—Wall anchors.

Wooden floor joists with two layers of 7/8-inch flooring supported by brick bearing walls are most commonly to be found in buildings of cheap construction intended for use as stores or residences where ordinary precautions against fire are suitable

and where no great strength in the floor construction is necessary. With joists 16 or 24 inches on centers, the flooring is quickly placed and no unusual arrangements need be made for supporting lath and plaster ceilings.

Floors with beams or girders of large cross-section, supporting floor sheeting composed of 3- or 4-inch plank with a wearing surface of maple flooring, are mostly employed in buildings with brick walls intended to be used for manufacturing or storage purposes, where heavy loads have to be carried.

Buildings with this type of floor system constitute the real mill construction so highly favored by fire insurance companies. Such buildings possess great strength and fire-resisting qualities and, due to simplicity of framing, they are quickly and cheaply erected. The walls and undersides of the floors in buildings of mill construction are usually unplastered. As all lumber is surfaced on all four sides and the corners of all beams, girders, and columns are chamfered, the interiors present an orderly and attractive appearance.

Designs calling for brick walls and steel beams are usually employed in structures where the floor loads are heavy and where it is desirable to obstruct the floor areas as little as possible with columns. This necessitates long-span beams and girders. This type of construction gives, as near as it is possible to obtain it, a strictly fireproof building. Where this type of floor system is used in the construction of a manufacturing plant, the walls and undersides of the floors are usually left unplastered. Where the buildings are to be used for offices or similar purposes, the walls and underside of the floors should be covered with plaster laid on metal lath.

BRICKLAYING METHODS

Starting a Wall.—In laying the brick in the lower part of a building wall, the bricklayer stands on the ground until the brickwork has progress to a height of about 4 feet when some sort of staging becomes necessary.

Inside or Outside Scaffold.—The scaffold may consist of planks supported on horses or barrels or a scaffold may be built. The decision as to whether or not a scaffold erected on the outside or the inside of the wall is preferable, is influenced by several considerations. In a general way, it may be said that a scaffold on the outside is preferable to one inside for several

reasons. The face brick may be laid from an outside scaffold without any overhand work; consequently, a better quality of workmanship may be obtained. The outside scaffold does not interfere with the work of the other trades and this is a distinct advantage where work is done by various subcontractors.

Inside Scaffold.—An inside staging is useful on small buildings with wall-bearing beams where exacting care in the appearance of the face brick is not required and where the staging will not interfere with the other building operations going on at the same time. The staging is usually built of platform planks resting on scaffold horses, the latter being placed on the floor beams at each story. As soon as the floor joists are laid for each story, the bricklayers may start laying the brick while standing on the floor until the work has progressed to a height where staging is necessary. The scaffold horses and planks are then placed on the floor, and the brickwork is laid up to the height of the next floor joist, when the operation is repeated.

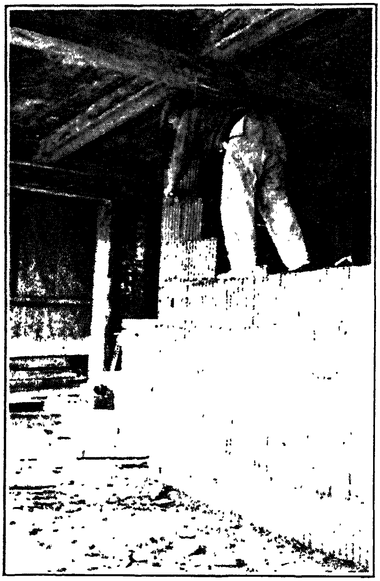


FIG. 184.—Setting partition tile.

Handling Materials.—The usual form of building having brick walls is designed with floors at regular intervals in height, varying from 9 to 12 feet from floor to floor. With this simple type of construction, the most convenient method of handling materials for the brickwork is to raise them inside the building and to convey them across at the different floor levels to the walls. The materials may be then passed out through the openings to the scaffold platform on the outside of the building where the bricklayers are working. With an inside scaffold, the materials may be raised inside the building as before and carried in hods to the platforms.

Where the building is only one or two stories in height, the materials should be carried in hods by the masons' helpers.

Where a building is three or more stories in height, it is generally assumed that some sort of elevator or hoist is necessary.

In the design of power houses, armories, and similar buildings, the roof is often 75 to 100 feet above the ground and the floors are frequently spaced many feet apart. The framework of the floors and roof is generally made of steel beams and girders. With this type of structure, a suspended type of scaffold either outside or inside the walls is most convenient. The materials should be raised by means of a material hoist tower and delivered to the platform of the scaffold either in wheelbarrows or in hods. It will be found most convenient to use a wide scaffold so that the materials may be wheeled on the scaffold in wheelbarrows.

Arranging the Work.—If the work is to proceed with maximum speed, the bricklayers should be spaced about 6 feet apart with a mortar tub for each man so arranged that, if the wall is broken by openings, one man will lay the brick in each pier or at least have an equal amount of wall to lay up. The mortar tubs and piles of brick should be kept away from the walls so as to provide a clear working space of about 18 inches for the bricklayers.

The hod carriers should move in gangs so that there will be no interferences or delays, occasioned in passing each other on the stagings, as well as to avoid any loitering by individual members of the gang.

Starting.—In starting a brick wall, the first course should be first laid dry, tentatively, to arrange the bonding of vertical joints and to provide for door and windows openings so that no closers will be required between the work of any two men. The first course on the foundation is often laid as a header course.

Leads.—The most experienced men are always stationed at the corners and keep the leads several courses of brick in height in advance of the main portion of the wall.

Sills.—Stone and concrete sills are set by the bricklayers and should be bedded in mortar at the ends only, the space between the brick and underside of the sill being allowed to remain unfilled to prevent the cracking of the sill as the green masonry settles.

Frames.—The window and door frames should be set by the carpenters. If an outside scaffold is used, the frames can be braced by braces extending diagonally from the frame to the floor. If an inside staging is used, it is preferable to have the braces extend horizontally from the window to a height at which they will not interfere with the staging and to fasten the other

end of these braces to a line of 2 by 4 topped with a horizontal plate of the same cross-section.

The sills of door and window frames should be set in a thin bed of mortar. The frames are carefully plumbed in both directions, the position on the stone sill having been first carefully marked on the latter with a pencil. A few loose bricks are then piled on the wooden sill to hold the frame steady.

Protection.—The tops of all brick walls should be protected each night from the washing effects of rain by boards placed on top of the walls and weighted with loose bricks to prevent their displacement by the wind. With union labor, this detail, as well as the cleaning of the mortar tubs, is taken care of by the laborers.

Cleaning Walls.—When the bricklaying is completed, all stains and loose mortar should be removed from the surface of the wall by brushing it with stiff brushes and washing it with a solution of muriatic acid. The acid-and-water solution should be mixed in wooden pails and applied with flat brushes with wood-fiber bristles. These brushes are known in the trade as "acid brushes." They are about 7 inches wide and similar in shape to whitewash brushes.

A weak solution of the acid will give much better results than a strong solution. A too-strong solution of acid will burn the brick, give the surface of the wall a greasy appearance, and destroy the natural coloring of the brickwork. A 5 per cent solution is often specified which is about equal to 1 pint of acid to 3 gallons of water. Usually, it is not convenient to proportion the solution accurately on the job and, as a practical matter, the correct proportion is attained by trial. The acid is added gradually to a pail of water until the solution is of sufficient strength to cause effervescence when sprinkled upon dry mortar.

LEAKS IN BRICK BUILDINGS

A building of masonry construction, although built with care, may permit the entrance of rain water in some part of the structure. Leaks usually appear several months after a building has been completed. They may occur in almost any portion of the building and be caused by a number of defects. The prime cause of the greater number of leaks is the shrinkage of cement mortar. Other causes are: failures in sheet metal work from contraction in cold weather, faulty construction around windows

and doors, lack of proper flashing, and careless masonry work.

The east walls of buildings in the eastern part of the United States need to be constructed with the utmost care, if leaks are to be avoided, as the heaviest wind-driven storms come from that direction. Occasionally, trouble will be experienced with a north wall. The south and west walls will seldom show any considerable leakage.

Leaks are more likely to become evident in the cold winter months than in warm weather. The reason for this is that the most severe storms occur during the colder months and continue for the longest duration. With cold temperatures, the materials in the exterior walls of a building contract, and any fine cracks or small apertures are increased in size and thus provide an easier path for leakage.

Leaks through Brick Walls.—To gain positive information about leaks through brick masonry, the author built several test

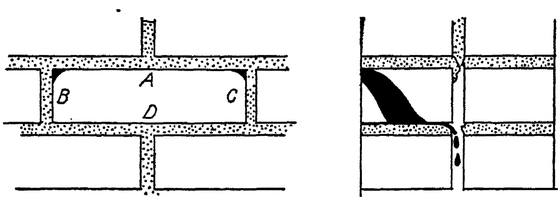


FIG. 185.—Typical leak.

walls of common brick. The bricks were laid with ordinary care and joints were tooled in various ways. Different mortars were used. The test walls after being built were left undisturbed for several days until the mortar had had time to set properly. A stream of water was then directed against the surface of each wall for 16 hours. While still wet, the walls were torn down, brick by brick, and the position and origin of all leaks were noted. Figure 185 has been prepared to illustrate a typical leak through a brick wall. Over 75 per cent of the leaks resemble the one shown in the figure.

As a result of the tests, the following facts were noted:

1. Leaks occur always between the mortar and the brick.

2. They are caused by the mortar shrinking away from the surface of the bricks.

3. Ordinary mortar is practically impervious to water.

4. Common bricks and unglazed face bricks absorb water and become saturated and in that way add materially to the passage of water.

From an inspection of the test walls, it appeared that 90 per cent of the leaks occurred in the vertical joints along the sides *B* and *C*. The two upper corners of sides *B* and *C* if broken or chipped are always the source of a leak. If the corners are perfect, there will seldom be a leak at those points. A leak will almost always occur where a brick is cut to a fractional length. The leaks at chipped corners and at cut bricks are caused by the mortar shrinking and drawing away from the broken surface of the bricks. Cracks in bricks do not cause leaks unless they run clear through the bricks.

With bricks laid in the ordinary way, the mortar in the vertical through joints shrinks away from the sides of the bricks in hardening. If all the joints were filled perfectly with mortar, each brick would be surrounded on all sides by an impervious envelope of mortar and no water could get through the wall, but the joints are never perfectly filled and the mortar will always shrink away from the sides of the bricks. This shrinkage shows as a fine hair crack on the surface of the wall between the mortar and the brick. The vertical joints between the tiers of brick are seldom filled solidly. Each leak has the appearance shown in Fig. 185. Water enters through the vertical crack between mortar and brick, usually at the upper corner, drains out in the rear into the joint between tiers, and, collecting there, eventually finds an outlet through the rear of the wall.

There will usually be more leaks through the header courses than through the stretcher courses because there are more vertical joints there and the joints run deeper into the wall. Also, any leakage from the wall above is likely to collect over the headers. There is less leakage with a thin joint than with a wide joint, as there is less thickness of mortar to contract and consequently the shrinkage cracks will be finer.

It is evident that the vertical joints should be filled as solidly as possible. However, while it is desirable to fill the vertical cross-joints, a path for leakage will still exist if cracks are allowed to develop by the shrinkage of mortar from the sides of the bricks.

To avoid leaks, the shrinkage cracks between mortar and bricks should be prevented from forming and the vertical joints

between tiers should be filled solidly with mortar. To prevent shrinkage, a sticky mortar should be used and the surface of the joint should be rubbed and consolidated with a slicker, so that the mortar is pressed hard against the sides of the bricks. If the mortar adheres to the bricks for the first 1/8 inch in depth, no leak can occur. A dry porous brick quickly absorbs water from mortar by suction. This causes the mortar in contact with the brick to dry before it has time to set and causes it to draw away from the brick slightly. In setting, the separation is increased. For this reason, all porous bricks should be wet before they are laid in a wall.

Theory of Action.—The problem of preventing leakage through brick walls has always been troublesome and baffling to builders, especially near the seacoast. The best explanation the author can give of the action that takes place is that capillary attraction, assisted by gravity and a slight but effective pressure from wind, draws the water from the surface of the wall through the fine hair cracks into the interior. This capillary action not only draws the water from the surface of the wall but also draws water from face bricks that are saturated to the point of being what may be called dripping wet. Where header bricks occur, this action is more pronounced due to the length of the fine cracks along the sides of the headers.

That this theory is correct seems to be verified by the fact that where rain descends at a slight angle against a wall in which holes several inches square have been cut, no water will enter the holes but leaks will appear on the interior of the same walls where the brickwork appears to be in fair condition.

Prehydration of Cement.—To avoid the contraction of mortar in the joints of brick masonry, a new treatment for portland cement is being developed which is known as prehydration.

The initial set of portland cement occurs in about 2 hours after mixing with water. Over 60 per cent of the contraction takes place during this period. To utilize this principle in securing water-tight joints in brick masonry, it is necessary to mix the mortar 2 hours before using. The mortar is mixed to a very dry consistency. Only enough water is added to make the batch similar to damp earth. The quantity of water should be small to avoid crystallization and the complete chemical action of setting. This is important. After the batch has been mixed 2 hours, more water is added to bring the mortar to the

desired plasticity and it is then served to the bricklayers for use in the wall.

When the mortar is prehydrated this way, it becomes very plastic and it is not necessary to use any lime to gain workability, the mortar consisting of cement and sand only. The contraction of the cement occurs in the mixed pile instead of in the wall and only a small percentage of its strength is lost.

Recommendations.—To attain leakproof brickwork the following recommendations may be made: Select impervious face brick. Lay the bricks with thin joints, not over 3/8 inch thick. Butter all face bricks on the bottom edge. Lay the face bricks in an overfull bed of mortar so they can be shoved endwise into place, filling the vertical joint completely with mortar. Employ a tightly packed and tooled joint. A weathered joint is good. It should be made with a slicker and should be carefully tooled. A weathered joint made with a trowel can not be so well formed. Use a very plastic mortar pressed firmly against the sides of the bricks. Pay particular attention to header bricks and soldier courses. Do not lay any bricks with chipped corners in the face of the wall. Wet all bricks. Lastly, inspect carefully each course of brick as soon as pointed, so that there will not be any small holes or fine cracks between the mortar and sides of bricks. When cleaning the walls with acid, take time to point up any defects.

Pointing Brickwork.—Leaks through the joints of a brick wall can be stopped by pointing up the cracks with mortar. The mortar used for pointing should be made with materials similar to those in the original work and mixed in the same proportions, so that the pointing mortar will have the same appearance as that in the wall. As a preliminary to pointing, each crack large enough to be the source of a leak should be cut out with a cold chisel. Water should then be applied to the joint with a brush to moisten it. A small chisel with a cutting edge about 1/2 inch wide is best for this work. It is not necessary to cut out all the mortar in the joint. It is sufficient to cut into the crack and widen it, so that mortar can be pressed into it with a small jointing tool or a pointing trowel. Care should be exercised to fill the crack neatly without spreading any surplus mortar over the face of the bricks, as this would mar the appearance of the wall. If the face bricks are porous, they must be given a coating of some material that will make them impervious to water.

Leaks through Copings.—The vertical joints between coping stones are a frequent source of leakage. A leak through a coping will let water into a wall, and may destroy plaster several stories below. Figure 186 represents the cause of such leaks. The cement mortar in the vertical joint between coping stones shrinks in setting and pulls away from the coping stones on each side of the joint. The movement results in forming two well-defined open cracks through which water will find an unobstructed passage. In cold weather the materials in the coping contract with the fall of temperature and the cracks become wider. To prevent these leaks, the top of the brickwork under the coping can be covered with sheet copper, or copper strips can be placed under the coping joints in such a way as to lead any leakage out of the wall. When the coping stones are laid, the mortar in the vertical joints should be raked out to a depth of about ¼ inch and the space should be filled with a plastic calking material that will adhere. Leaks in a coping will occur unless particular care is exercised to prevent them.

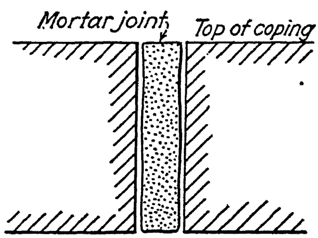


FIG. 186.—Joint in coping.

Leaks in the joints of a coping can be stopped by covering the joints with a plastic calking material similar to those used around windows and doors. Such materials resemble putty in appearance and consistency. They remain pliable for years and adhere even to metals with great tenacity. They contain vulcanized china wood oil which gives the materials great elasticity and waterproofing qualities.

Leaking joints in a coping may be repaired by pointing up the cracks with a portland cement mortar, but while the pointing mortar will remain in place in the majority of places, in some others it will loosen and fall away. Plastic roofing cement can be used for the same purpose where appearance is not important.

Leaks through Cornices.—A leak through a stone cornice is a thing of common occurrence. A casual inspection of almost any stone cornice from the ground will show the discolorations and white stains that always accompany such leaks. A dark brown area in limestone after a storm indicates the presence of water in the wall due to a leak somewhere above the stain. A leak in a stone cornice is occasioned by the shrinkage of the cement

mortar in the vertical joints in the same way as between coping stones. The leaks can be stopped by cutting out the mortar in the vertical joints to a depth of ¼ inch and filling the joint with a plastic calking material. The joints can also be repointed with a cement mortar, although the latter may loosen and fall out in time.

Leaks in Composition Roofing.—Very few leaks occur through the body of a composition roof. Blisters in asphalt roofs are of common occurrence. The blisters should be cut open and relaid, preferably with hot asphalt.

Water frequently collects under the roofing in the corner cricket where the roofing material is turned up against a brick parapet wall. This condition reveals itself as a blister in the roofing. The water is generally traceable to leaks in the masonry of the wall or the coping. Water finds its way under the roofing from the wall and remains there for a long time, as there is little possibility for evaporation. These leaks can be repaired by stopping the leaks in the wall, opening the roofing material over the blister, and relaying the roofing with hot asphalt or plastic roofing cement.

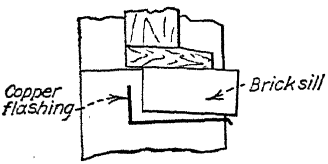


FIG. 187.—Flashing under brick sill.

Leaks around Windows and Doors.—The space between the frame of a window or door should be calked with hemp and finished with a coating of calking material. The joint between the frame and the sills should be pointed up with calking material or cement.

Window sills made of bricks laid rowlock will usually leak. The cement mortar in the many joints between bricks will shrink away from the sides of the bricks and let water enter. Brick sills should always be backed up with a copper flashing, as shown in Fig. 187.

FIRE BRICKS AND BOILER SETTINGS

Fire Brick.—Fire bricks are solid blocks of a refractory mixture of silicates and clay. They are made by the dry- and stiff-mud processes. They may be classified into groups, in one of which the silica predominates, another in which clay predominates, and the third, in which the silica and clay are about equal. Fire bricks fuse under the heat of a furnace at about 3100°F.

Size.—The standard size of a fire brick is 2½ by 4½ by 9 inches. Few bricks, however, will be found having exactly these dimensions. Bricks shrink during the burning process of manufacture, and in spite of constant efforts of the manufacturers to turn out bricks of equal dimensions and straight edges, only a small proportion of the bricks will be found to be perfectly shaped and true to size. The matters of shape and size influence greatly the amount of care necessary to secure perfect workmanship in laying fire brick.

Fire Joints.—Fire brick should be laid with the thinnest possible joints. The joints showing on the face of the wall are the most important as they are exposed to the direct action of the fire. The first action of the fire is to melt and fuse the fire clay or other filling material in the vertical joints. As soon as the material in the vertical joints becomes fused, it has a tendency to flow downward, gradually leaving the joint open at the surface and exposed to the action of the fire. It is necessary, therefore, to pay special attention to those vertical joints. The fused fire clay and the fused surface of the bricks, combined with mineral matters from the fire, cover the surface of the brick in time with a slate-colored slag which is an excellent refractory material and serves to protect the brickwork from the effects of the fire.

The joints in fire-brick work are filled with fire clay, preferably of the same clay from which the bricks are made.

Laying the Brick.—Each brick before being placed in the setting should be dipped in a batter of fire clay. Each brick should be coated with the dip on all sides which will be in contact with the other bricks, and then placed in position in the wall. To bring the brick well up against the ones adjacent to it in the same course and to insure tight joints all around it, the brick should be rubbed back and forth against those previously laid until it works snugly into place. To make sure that the brick is properly bedded, it should then be tapped on the top and sides with a hammer. The resulting joint should not be wider than the thickness of the blade of an ordinary pocketknife.

Fire brick are laid by working to a line as in ordinary brickwork, and the walls are kept plumb with the mason's level.

Fire Clay.—The fire clay for the joints is prepared by mixing it with water in a watertight mixing box until it has the consistency of a thick cream. This mixture is called a "dip." The dip should be made several hours before it is to be used so that

the clay is thoroughly soaked. Fire clay is not a cement. It merely fills the joints and prevents the passage of gases until it fuses; then it becomes welded to the materials of the brickwork.

Fire clay is being slowly superseded by various cements which are especially suited to stand high temperatures. The strictly high-temperature cements fuse around 1200°. They act merely as a filler in the joints until they fuse under action of the fire. They are recommended for temperatures up to 3100°.

Another class of cements which is available sets up in air, like portland cement. They may be used where the temperatures do not exceed 2600°.

Defects in Fire Bricks.—Fire bricks should be 2½ inches thick. They vary from this thickness by being either slightly thicker or thinner than 2½ inches. Some will measure exactly 2½ inches

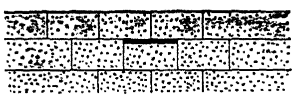


Fig. 188.—Variation in thickness.

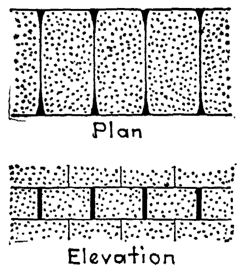


Fig. 189.—Results of curved side

thick. If bricks of different thicknesses are laid in the same course, wide bed joints will result, as in Fig. 188.

Fire bricks should be straight along the sides. Ordinarily, the tops and bottoms of the brick will be true but the sides will be curved. Curved sides prevent good vertical joints, as shown in Fig. 189. The darker brick are most likely to have the curved surfaces. The lighter-colored brick are more true in shape.

The corners of fire brick should be sharp and perfectly formed. If the brick are handled frequently or carelessly or jostled much during transit, the corners become chipped and rounded and the bricks will be unsuited for the face of a wall (Fig. 190).

Bricks should all be 9 inches long but they vary. The light-colored bricks will be nearly true to size; the dark-colored bricks will be much shorter, frequently measuring 8½ inches. When the surface bricks are backed with other fire brick, this difference in length will result in wide vertical joints between the two tiers of brick (Fig. 191).

Boiler Settings.—The brickwork of a boiler setting consists of an internal lining of fire brick and exterior walls of red brick. The red brick should be laid in a mortar made of one part of lime paste to three parts of sand. Standard specifications for proportioning the mortar usually call for a small quantity of cement to be mixed with the lime; one part of cement to six parts of the lime paste by volume is often specified. Pure portland-cement mortar should not be used, as portland cement does not stand up

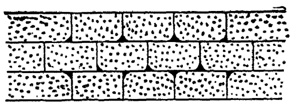


Fig. 190.—Result of rounded corners.

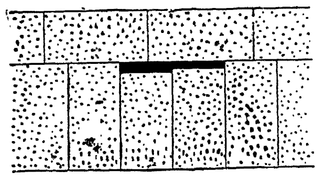


Fig. 191.—Result of varying lengths.

well when subjected to the heat encountered in boiler settings. The joints between the red brick should not exceed 3/8 inch in thickness.

The fire brick should be laid in fire clay or a dip of refractory cement. The wall of red brick and the lining of fire brick should be brought up together, the fire brick and red brick bonded together every third or fifth course by extending the fire brick into the red brick.

The heat of the furnace fire, if intense, heats the fire brick to incandescence and causes an appreciable expansion of the fire-brick lining. While the effect of the fire on the red brick is to expand them, it has a more appreciable shrinkage effect on the mortar, particularly on the mortar of the vertical joints. The exterior walls of boiler settings will usually be marked with cracks, following the vertical joints.

The fire-brick lining of the fire-box portion of the boiler should always be lined with header brick, giving a lining 9 inches in thickness. The thickness is desirable as a protection against the intense heat as well as against any wear from the tools used on a coal fire. The remainder of the interior of the boiler setting may be lined with stretchers, giving a thickness of 4½ inches of fire brick.

Bridge Wall.—The bridge wall receives the most destructive effects of the fire and consequently becomes very highly heated, expanding lengthwise a considerable distance. For this reason,

the bridge wall should be arranged so that it may expand toward the ends and be free on all sides to move. This is termed a "floating" bridge wall. If no arrangements are made to allow free expansion and movement of the bridge wall, the brickwork, when heated, will bulge outward, opening up the vertical joints and thus exposing them to the melting action of the fire. The upper portion will also tend to bulge upward, opening up the bed joints in a similar manner. The expansion of fire brick will amount to about 1 per cent at the usual intense heat of 2800°.

The end of the bridge wall should be housed into the fire lining of the side walls about 2½ inches, and a vacant space of 2 inches should be left at the ends for the expansion of the wall. The fire-brick lining of the side walls should be kept away from the

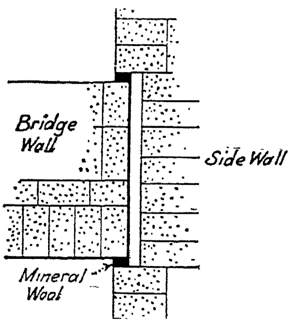


Fig. 192.—Expansion joint, end of bridge wall.

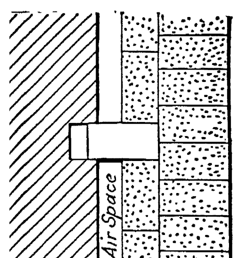


Fig. 193.—Air space between fire brick and red brick.

brick of the bridge walls about 1½ inches and the space so formed closed against the direct effects of the fire by a calking of mineral wool, asbestos rope, or similar refractory material, forming a sort of stuffing box in which the bridge wall may move (Fig. 192).

Side Walls.—The side walls of a boiler setting are usually protected from the effects of the fire by an air space 2 or 3 inches wide in the interior of the wall, usually between the fire-brick lining and the exterior red-brick wall. This air space is very effective in cooling the walls and will usually prevent excessive expansion or bulging and cracking, and should be provided with vents to the outside air.

To unite the walls across the air space and preserve their structural strength, header brick of the fire lining should extend across the air space. Care must be exercised to prevent any chips

or mortar from getting into the air spaces and voids left for expansion. This may be accomplished by pieces of wood which are inserted in the spaces and drawn up as the work progresses, or the spaces may be filled with cotton waste to be removed later or allowed to remain to be burnt out by the fire.

Boiler settings containing an air space in the walls are going out of favor and are being superseded by settings designed with solid walls.

Drying-out Fire.—New boiler settings contain a certain amount of moisture which it is necessary to dry out before a large coal fire can be started under the boilers; otherwise the brickwork will crack badly. For this reason a small wood fire should be built in the fire box and kept burning continuously for several days until the brickwork is thoroughly dried out. This is, in fact, a sort of soaking process in which time must be given for the heat to penetrate through the entire thickness of the walls before the coal fires are built. The boilers should be filled with water before the drying-out fires are started.

Fire brick should always be kept dry. Fire brick which have become thoroughly wetted seem to lose their cohesion and power to resist the effects of high-temperature fires. In particular, care should be exercised to have the fire brick dry when laid in the walls of the furnace or the boiler setting. Wet brick in the walls furnish additional moisture which must be dried out, and any brick which contains an excess of moisture is likely to be spalled by the fire.

CHAPTER VII

STEEL CONSTRUCTION

General.—The work of erecting the structural-steel frame of a building is more purely a matter of assembling than are most other lines of construction work. The structural members of the steel frame are fabricated in the shop and each piece is marked with letters and numbers to distinguish it from the other pieces of the framework.

The plans for the steel erection are known as "erection plans" or "erection diagrams." They differ from the usual construction plans in that they consist of simple single-line diagrams drawn with the object of indicating the position in the building of each piece of the steel framing. The location of each member is shown by the position of the number designating it on the diagram.

If the building operation is of considerable size, it will be found advantageous to have the same company do the erecting that has the contract to fabricate the steel. This is particularly true where the building rises two or three stories or over. Low one-story structures may often be erected with unskilled help, particularly where the connections are to be bolted.

The methods used in erecting steel buildings vary with the type of structure. Formerly, gin poles were used a great deal more extensively than at the present time. The tendency is toward the use of steel guy derricks, cranes, and A-frame travelers. The sequence of operations in all cases is very similar, starting naturally enough with the columns and ending with the roof trusses and cross-bracing.

Erection of Columns.—The columns of light one-story buildings can be erected by hand or if heavy they can be most conveniently erected by means of a "dutchman" or pole derrick (Figs. 318 and 319), having a winch bolted to the mast. In buildings of heavier construction, it may be desirable to make use of a device such as shown in Fig. 322. This apparatus is often referred to as a "monkey." It is usually operated with

power furnished by a steam hoisting engine or by a winch stationed on the ground some distance away. A small gin pole may also be employed but these methods require a snatch block at the base of the apparatus. The necessity of providing anchorage against the pull of the snatch block may prove inconvenient when the apparatus has to be moved frequently. In such cases, a chain block hung from the top of a dutchman of heavy construction may be used. The rate of lifting with a chain block, however, is very slow and this method consumes considerable time.

When a building of one or two stories covers an extensive area, the steel framework may often be advantageously erected by a revolving crane or by a variety of traveler known as a "jinniwink." The revolving crane and jinniwink are very efficient machines; they may be as useful in erecting the other members of the framework as in erecting the columns.

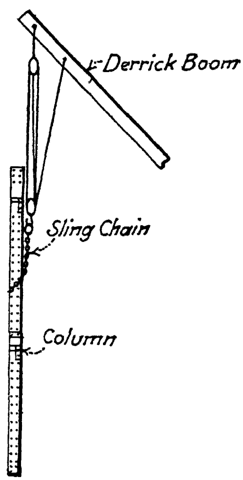


FIG. 194.—Erecting a column.

Buildings which rise over two or three stories in height are usually erected by guy derricks. The columns in such cases are lifted by the derrick and set in place on the foundation. A steel column can be handled by a sling chain placed around it just above the center of gravity. The chain should be equipped with a round hook and ring. The ring is engaged by the hook of the hoisting tackle, the hook of the chain being carried around the shaft of the column and hooked over the chain to form a slip noose (Fig. 194). An advantage to be had in using a chain is that, when slacked off, it will loosen and slide down the column until it is accessible. It is not necessary, thus, to send a man up the column to loosen it. The use of chains in erecting steel is not permitted in some cities, because there is danger of a chain breaking. Slings of wire rope are preferable.

The columns of tall buildings are made in two-story lengths, the splices coming just above the girder connections at every second-floor level. Before the foot of the upper column section can be inserted between the splice plates riveted to the top of the lower section, it is often necessary to bend the splice plates outward slightly by sledging them. As the column is lowered

into place, the connection holes should be guided into line by inserting the spud end of a structural wrench into them. The splice connection should be temporarily secured by four bolts in each splice plate. One or two drift pins should be inserted in the holes of each column splice. The drift pins have exactly the same diameter as the holes and hold the column rigid and prevent it from rocking back and forth with the wind, until the horizontal beams and other members are connected. The drift pins should be taken out and replaced by bolts before the building is plumbed, as the pins will interfere with plumbing the building.

In steel erection work, a raising gang will usually consist of six men, a foreman, an engineer, and at times a fireman. The six men of the gang include one boom man on the bull-stick, one signal man for the bell, two men hooking on, and two men connecting up. When the gang turns to riveting, two of the men may be assigned to bolting or may be laid off.

Setting Base of Column.—The top of the concrete foundation may be prepared in various ways for receiving the foot of the columns. To enable the shaft of the column to set exactly plumb, it is necessary that the base plate of the column should be placed level. It is the practice of some engineers to build the foundation slightly above grade and later to chip and bush hammer it down to the exact grade fixed for the bottom of the base plate. Another method is to embed a steel plate in a thin bed of grout on top of the foundation with its top surface set exactly to line and to the correct grade.

The method most often employed is to build the concrete foundations up to an elevation which is approximately $\frac{3}{4}$ to 1 inch below that intended for the bases of the columns. The columns are then set with the bases at the correct elevation, the 1-inch space being filled later with a cement grout. The grout should be mixed in the proportions of one part cement and two parts sand with sufficient water to make it flow easily.

When the latter method of grouting the base plates of the columns is to be employed, each column should be set on four wedges inserted in the space between the top of the concrete foundation and the base plate of the column. The wedges should be made of steel about $2\frac{1}{2}$ or 3 inches wide and about 6 inches long and 1 inch thick. It is the better plan to set the base of the column on steel shims to the exact elevation when the column is placed on the foundation rather than to adjust it later,

when the weight of many tons of steel overhead would have to be lifted. The shims can be set to grade in advance of erection.

Erection of Girders.—Girders and beams can be best erected by means of bridle slings made of wire rope. The bridle should be equipped with round hooks. The girder should travel from the ground to its location in the building in a horizontal position with its web vertical at the same time. To this end, when attaching the sling, the hooks should be taken around the girder in opposite directions (see Fig. 195).

When the erection is being done with a guy derrick, the girders and beams farthest away from the derrick should be set first, working completely around the circle so that the derrick is not shut in until the last piece of steel is placed. Girder beams may be swung sideways into place where the connections to the columns consist of top and bottom seat angles and where ½-inch or more clearance usually is provided between the end of beam and column. When the connection of girder to column is made with angles flush with the end of the girder and intended to be riveted tight against the flanges of the columns, it will usually be necessary to spread the columns apart slightly to get the girder in place.

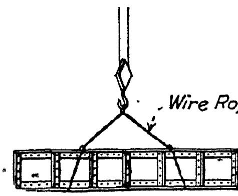


FIG. 195.—Erecting a girder.

As the girder is swung into position, the rivet holes are brought into line by inserting the spud end of a wrench into the holes. All beam connections should be secured temporarily by four bolts in each end. Heavy girders should have more.

Cross-bracing.—The erection of the vertical cross-bracing is important as during its erection the building can be plumbed and the column bases can be grouted. As a matter of fact, as soon as the vertical cross-bracing has been bolted in place, the structure will usually be plumb.

The work of erecting the cross-bracing is simple. If the bracing is light, it may be hoisted by hand or, if a derrick is being used, by the latter. Usually a sling of manila rope is sufficient to lift it. The rivet holes in the ends of the braces may not come fair at first with those in the connections on the columns, due to the columns being out of plumb. The holes may be brought into line by pulling on the framework in the proper direction with wire cables and turnbuckles or with ordinary hoisting tackle.

Where the bracing consists of two angles or channels riveted back to back and it is necessary to slip them over a gusset plate riveted to the column, the angles or channels, as the case may be, should be spread apart at the ends of the member by drift pins driven between them (Fig. 196).

Erection of Trusses.—Small trusses are often shipped in one piece, more usually, however, ordinary roof trusses are shipped in sections. The usual Fink truss is customarily shipped in three pieces consisting of two half trusses and a section of the bottom

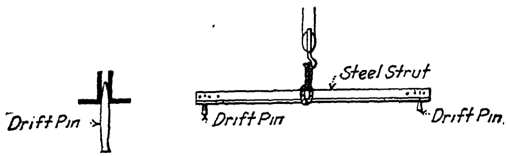


FIG. 196.—Spreading ends of strut.

chord. These three sections have to be riveted together in the field.

A roof truss may be erected by means of a gin pole, a derrick, a revolving crane, or a jinniwink. It may be lifted by a chain, wire rope sling, or a rope lashing thrown around the top chord. If the truss is fabricated of very light structural shapes, it may not possess very great lateral strength and it may be desirable to reinforce it by a piece of 4 by 6 or a similar timber lashed along its side to prevent it from being bent sidewise during erection.

The truss may be assembled and erected with the sections bolted together temporarily, the riveting being done later at the same time the riveting in the top- and bottom-chord bracing is done. It will be found more convenient, however, to assemble the truss flat upon the ground, riveting the sections together while on the ground. In some cases, where there are two or more stories to the structure and a derrick is not being used in the erection, it may be found convenient to assemble the truss sections on the upper floor and to rivet them together there.

When the first truss has been raised and connections to columns have been bolted, it is necessary to guy it temporarily against overturning. Four manila-rope guys should be fastened to the top chord. The second truss should be erected in a similar manner. The purlins and vertical bracing between trusses should be erected next. The vertical cross-bracing helps greatly at this point in the erection. After it is in place between trusses

and several of the purlins have been bolted fast, the guys may be taken off and the trusses may be allowed to stand alone.

Top-and Bottom-chord Bracing.—The horizontal bracing usually consists of light members which can be hoisted by hand lines. The principal longitudinal struts in the bottom chord are made of angle irons and are easily erected. The diagonals in top and bottom chord are usually rods with both ends threaded about 6 inches. Each end should be provided with two nuts.

A roof truss lacks rigidity when first stood in place and may be readily deflected sidewise until the diagonals of the top and bottom chord are installed. When the diagonals have been inserted, the entire framework becomes rigid.

To put the diagonal rods in place, the outside end nuts must be taken off and the inside nuts must be screwed back to the end of the thread. The rods may be inserted, then, in the holes and the outside nuts screwed on the rods again, both nuts being screwed tight against the fastening.

Erection of Purlins.—Roof purlins on the majority of steel buildings consist of channel irons or lightweight steel beams. Usually no tackle is necessary to raise these. A small line equipped with a hook or shackle which is inserted in the end connection holes of the purlin and pulled up by two men stationed on the truss at each end is sufficient. If a derrick is on the work it may be conveniently utilized to set the purlins. Each man assigned to the erection of the purlins should be equipped with a spud-ended wrench and a supply of bolts. As the ends of the purlin are placed on the trusses the connection holes are brought into line with the spud end of the wrenches.

The bolts should be inserted through the webs of the channel with the nut end toward the back of the channel so that the nuts may be turned without interference between the outstanding flange of the channel and the wrenches.

The roof trusses may become slightly warped sideways through handling and it may be necessary to use drift pins and sledges or a light tackle to pull them into position. Where the holes in the purlins are considerately out of line with the holes in the trusses, it will be found convenient to bolt up such purlins as will fit, the connection of the others gradually coming into line as more purlins are bolted up.

Tie Rods.—Tie rods are short steel rods usually 5/8 inch in diameter. They tie the beams of a floor system or the channel

purlins of a roof together so that they cannot deflect laterally while supporting a load. The tie-rod holes in the webs of the purlins are spaced about 5 inches apart. The tie rods are staggered in adjacent spans. The rods should be 4 inches longer than the distance back to back of purlins and should have a 6-inch thread on each end. Each threaded end should be equipped with two nuts.

To insert the tie rods in the holes, the end nuts must be taken off and the inside nuts must be screwed down to the end of the thread. One end of the rod can then be inserted in one of the holes and pushed back as far as it will go, the other end being then in a position to be entered. If the rods are given an extra length it will be necessary to increase the length of thread on the ends. If a rod becomes bent in forcing the ends into the holes, it can usually be straightened by tightening the end nuts.

Plumbing of Buildings.—While the vertical bracing is being placed, the structure may be lined up and plumbed. As the first step in the lining and plumbing operation, the column bases should be brought to the correct grade if not already there. A derrick may be used in this work or a heavy jack and timber under one of the girders will lift the column sufficiently to allow the wedges under it to be adjusted properly.

When the column bases have been brought to the correct elevation they should be next shifted laterally until they are in alignment. To do this accurately, the locations of lines parallel to the theoretical column centers should be established a few feet off the column center. By measuring from these lines, the correct position of each column may be ascertained. The majority of the columns will usually be found to be off the theoretical line a fraction of an inch. A column can be moved into position by ramming it with the end of a steel beam suspended from above so that it may swing freely. It may be pushed laterally by a jack or pulled by a turnbuckle.

The column bases having been brought into line and to grade, the building is ready to be plumbed. The columns along the outside lines of the building should be tested first to see whether or not they are vertical. If the outside columns are vertical and all beams and girders are in place, the intermediate columns cannot very readily be out of plumb. A plumb bob weighing several pounds is hung along the sides of each exterior column to test it for being plumb, and the distance from the line by

which it is suspended to the column is measured near the top and bottom.

If the building is out of plumb, the vertical bracing cannot be made to fit and the structure will have to be pulled over at the top until the rivet holes coincide sufficiently to allow the insertion of the fitting-up bolts. The building may be pulled into a vertical position by ordinary tackle but a more satisfactory way is to use a length of wire rope attached to the steel frame, utilizing a guy tightener to do the pulling.

The guy tightener may be equipped with a hook at one end and an eye at the other or each end may contain an eye. The shank of the turnbuckle should be 1 or 1¼ inches in diameter. The drift of the threaded portion should cover a distance of 24 inches. The wire rope should consist preferably of a length of ½ or ⅝ inch pliable steel hoisting rope. The cables can be conveniently fastened around the columns at the floor beams. At the foot of the columns, it is customary to hook the cable to the columns with plumbing-up hooks. A piece of board should be inserted between the hook and column to prevent slipping.

In cases, where no vertical cross-bracing is provided as part of the structure, the steel frame should be cross-braced by steel cables pulled tight by a guy tightener inserted in each cable. There should be a pair of these cables on each side of the framework and on each bent of columns across the width of the frame. These cables should form a complete X, extending diagonally from the top of one column to the foot of another at the other side of the building. Ordinarily, a steel frame is cross-braced with cables along the outside columns only. When the end bents of the building have been plumbed transversely, a fine wire or a chalk line can be stretched along both sides of the building as a guide in aligning the outside columns of the intermediate bents. The intermediate bents can then be pulled over into position by one cable in each bent.

As soon as any portion of the structure has been brought accurately into a vertical position, the column bases can be grouted. The steelwork is then ready for riveting.

RIVETING

Fitting Up.—When the various members of the steel framework are in place, held temporarily by bolts, and the building has been

lined up and plumbed, the riveting gangs may start riveting the connections permanently together.

Before any rivets can be driven in any connection, it is necessary to bring all rivet holes into alignment for the insertion of the rivets. This is done by driving drift pins into the holes and forcing the holes into line. It is necessary that all plates, angles, or other shapes that are to be riveted should be drawn tightly together. For this purpose fitting-up bolts and washers should be freely used. A sufficient number of bolts should be used to hold the holes in line and to clamp the metal together. The bolts are taken out one or two at a time as the riveting progresses and rivets inserted in their places.

Fitting-up Bolts and Washers.—The machine bolts purchased for use as fitting-up bolts should have square heads and nuts. Two lengths of bolts will usually be sufficient. A length of $2\frac{1}{2}$ inches is suitable for bolting two thicknesses of metal and a length of 3 inches will serve for bolting three thicknesses together.

Fitting-up washers should preferably be about $\frac{3}{8}$ inch thick, so that rapid work may be done in bolting up a connection in preparation for riveting, several washers being necessary at times on one bolt to fill out the distance between the steel and the nut. The washers should be punched with a $\frac{15}{16}$-inch hole so that they may be used on either a $\frac{3}{4}$- or a $\frac{7}{8}$-inch bolt. The washers may be procured from any structural shop. It is customary to punch fitting-up washers out of structural scrap.

Drift Pins.—A drift pin should be driven through each hole with the riveting gun before a rivet is inserted. It is important that this be done. The drift pin clears a path through the hole for the rivet by removing all burrs and paint. It also draws the plates or shapes into line. A rivet swells when heated to a red heat and although the hole is punched $\frac{1}{16}$ inch larger in diameter than the rivet, it is none too large for insertion of the rivet.

A drift pin is made with the same diameter as the hole. A rivet $\frac{3}{4}$ inch in diameter calls for a pin with a diameter of $\frac{13}{16}$ inch. A drift pin with one long tapered end and the other with a blunt taper is preferable. A drift pin with a short taper at each end is not satisfactory for this work. The short taper makes it difficult to drive. Where the holes do not come fair, the pin becomes wedged in the hole and the small point at the other end soon becomes battered, chipped, and broken by the hammer.

Riveting.—A riveting gang consists of four men: two riveters, a rivet heater, and a bucker-up. The rivet heater heats the rivets in the forge, picks a red hot rivet out of the fire, knocks it against the forge to remove scale, and tosses it to one of the riveters. The latter raps the rivet against the steel work further to remove scale and inserts the rivet in the hole. The bucker-up presses the rivet home with the dolly bar and holds it in place while the rivet head is formed on the other end of the rivet by the other riveter. The dolly bar after the first second or two need only be pressed lightly against the rivet. The riveting hammer should be kept tightly pressed against the rivet head to prevent it from slipping off.

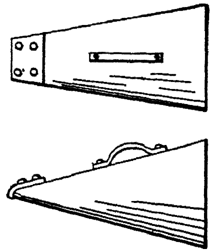


Fig. 197.—A rivet catcher.

Rivet heating is a specialty in itself and requires considerable experience and skill for its mastery. Rivet heaters as a rule do nothing else but heat rivets when working in riveting gangs. The rivet heater must be able to heat the rivets to the right temperature without burning them and must be able to toss them accurately through the air to the riveter, whose duty it is to catch them. The latter is provided with a can or pail for the purpose. A special device for catching rivets can be made of light sheet metal, as shown in Fig. 197. This rivet catcher has a handle and the small end of the cone is flattened so that the rivet becomes wedged and remains in a position where it can be conveniently grasped with the tongs.

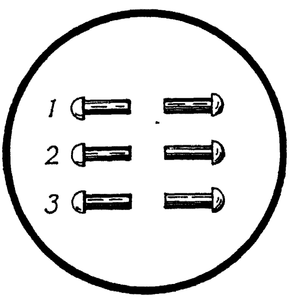


Fig. 198.—Rivets in a forge.

When a riveting gang is working fast, a hot rivet may be needed every half minute. From a rivet heater's viewpoint, the operation is continuous. One rivet is being driven, one tossed, another going into the fire. When supplying a fast gang, the rivets should be placed in the heating forge as indicated in Fig. 198. Rivet 1 is picked out of the fire with the tongs and tossed to the catcher who is working in the riveting gang. Rivets 2 and 3 are grasped with tongs and pushed forward, taking along the fire between them, at the same time. A new cold rivet is

put in the original position occupied by No. 3. It is necessary to lengthen the curve in the top jaw of the rivet tongs to take two rivets.

With a fast riveting gang six rivets should be kept constantly in the fire and arranged in two rows with the ends of the rivets turned toward each other in the center of the fire. This is to make certain that the shank of the rivet is heated thoroughly, as

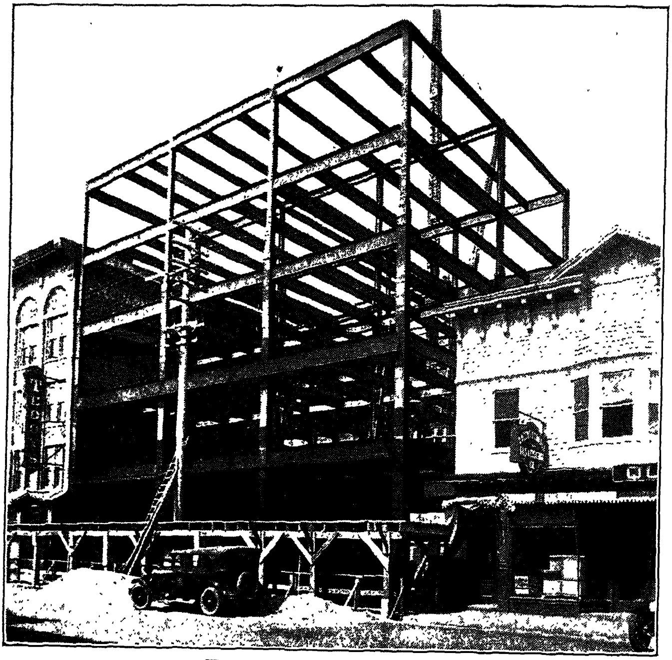


FIG. 199.—A steel frame.

it is more important to heat the shank thoroughly than it is to heat the head of the rivet. When the riveting is progressing slowly, the rivets may be arranged in a single row of four rivets.

The tongs used by the heater for picking the rivets out of the fire and tossing them to the riveter are especially designed for the purpose. The tongs are long, one of the jaws is slightly curved to fit the shank of the rivet. The handles of the tongs are very slender and light. The tongs used by the riveters to insert the rivet in the rivet hole are similar but of much shorter length.

The two riveters alternate in riveting and in catching the rivets, one riveting in the morning and the other in the afternoon.

The bucker-up usually continues holding the dolly bar without changing.

After being driven, rivets should be inspected for imperfect riveting. The chief imperfections in riveted work are loose and burned rivets. The latter may be distinguished by their appearance. Loose rivets are usually searched for by tapping each rivet with a hammer or other steel object. It is customary to inspect the riveting at any one connection before the riveting scaffold is moved. If the rivets to be inspected are cold, each rivet may be tested by tapping it on the head with a hammer, a finger being placed on the opposite side of the rivet head at the same time. The looseness of the rivet may be easily felt, the movement usually being evident on the other end of the rivet also. Very often the rivets are still hot when tested and a steel washer or other small piece of metal may be held against the hot rivet head to transmit the jar to the inspector's hand. A drift pin or any other object of hard steel may be used to test the rivets if a hammer is not at hand.

Riveting Scaffold.—Part of the riveting of a steel structure may be done from a platform of planks laid on top of the beams and cross-bracing, but over 90 per cent of the riveting must be done from small suspended scaffolds hung from the floor framing. A variety of needle-beam scaffold is invariably used for riveting work. Figure 200 represents a general view of a riveting scaffold. It should be hung at a distance below the connection to be riveted which will allow the men handling the riveting hammer and dolly bar to work efficiently.

As may be seen from an inspection of Fig. 200, the riveting scaffold consists of planks supported by two 4-by-6 spruce timbers 12 to 16 feet long hung from the steel framework by manila ropes 1¼ inches in diameter. The working platform consists of two tiers of 2-inch plank. Three or four 2-by-10 spruce plank about 8 feet long are placed across the 4-by-6 timbers, thus forming a support for three or four more 2-by-10 spruce planks about 16 feet long laid crosswise upon them. If occasion warrants, the longer planks can be laid on the 4 by 6 with the shorter planks uppermost. This arrangement allows considerable latitude in working range and permits this type of scaffold to be as readily hung around all four sides of a column, as under the connections of floor beams to girders. The planks are not fastened by nails or in any other way and, although hundreds

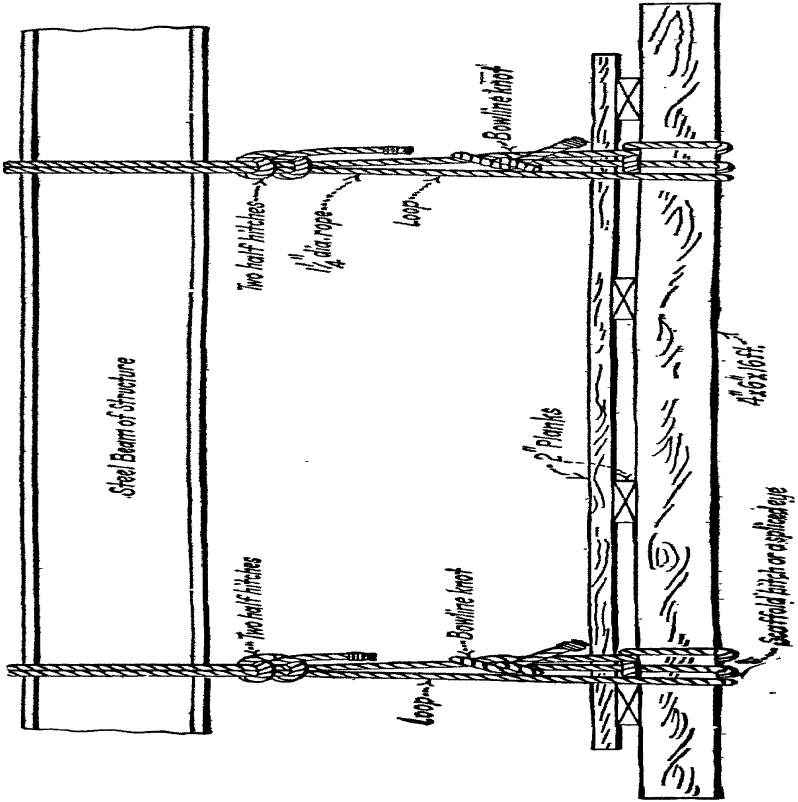
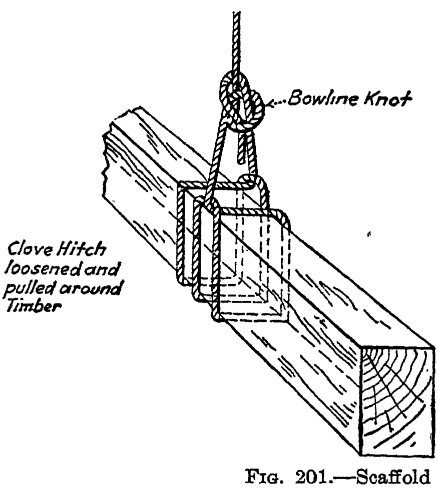


FIG. 200.—Riveting scaffold.

of these riveting scaffolds are in use every day, it is very rarely that any accidents occur from their use.

There is a special hitch used in hanging this type of scaffold which is known as a "scaffold hitch." The hitch holds the 4-by-6 needle beams securely and prevents any tendency to roll or turn over. The scaffold hitch is shown in detail in Fig. 201. It is really a clove hitch pulled open and used in combination with a bowline knot. The rope from the hitch is carried up over a girder or other support above, then down again, around the 4 by 6 and upward so that the latter hangs in a loop. The rope then is passed again around the support overhead and secured around itself by two half hitches, as shown in Fig. 200. An eye spliced in one end of the rope is commonly used as a substitute in place of the scaffold hitch just described. The rope should be long enough to permit the 4-by-6 timbers to be pulled up from the floor beams below. Ordinarily the rope should be 5 to 10 feet longer than the distance between floors.



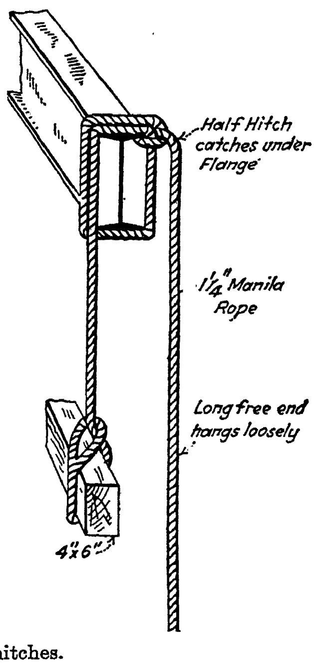


FIG. 201.—Scaffold hitches.

Erection of a Mill Building.—The majority of low one- or two-story buildings are of the type known as steel mill buildings. A brief description of the methods customarily employed in erecting a mill building will be found in a general way to be similar to those which would be naturally employed by ex-

perienced erectors in erecting any steel structure 20 to 30 feet in height.

If the quantity of steel will warrant it, a revolving crane or a jinniwink traveler may be used to erect the steel. The erection is started simply enough at one end of the structure by the erection of the columns at that end, followed immediately by the beams, trusses, and other steel framing connected to them. The machine is then backed away from the work already set until it is in a position to erect the steel forming the next bay. The operation is then repeated until the opposite end of the structure is reached.

The erection of a one-story mill building by means of a wooden gin pole is a matter of considerable detail and science. The power is usually furnished by a steam engine or a winch stationed at one end of the building.

A wooden gin pole should be rigged with a hoisting tackle at the top of the pole and a snatch block at its foot. The tackle blocks are placed on the side of the pole directly over the load. Unless there is a sheave in the pole, the rope from the hoisting tackle cannot pass through the pole but must pass down its side through the snatch block at its foot and thence to the engine. This brings the load and the engine on the same side of the pole.

This arrangement makes it necessary to start the erection on the end toward the engine and to progress backward away from the engine. From time to time, as it becomes necessary to change the location of the pole, it is pulled ahead by means of a rope secured to its foot, passing forward over a single block some distance ahead and thence backward to the engine. This rope is useful when hoisting a load to take the pull of the snatch block. It is then frequently termed a "kicker."

The top of the gin pole has to be adequately guyed and sufficient anchorages should be provided in advance for them so that there will always be anchorages conveniently located for each new position of the pole, as it is moved.

The columns must first be set as an independent operation either with a "dutchman," "monkey," gin pole, or other device, moving the apparatus from one column position to another. As soon as the columns in one bent are set, the truss may be erected and guyed and the pole moved to a new location. It will be found advisable to permit the pole to remain fastened to the truss next erected until the purlins and bracing in the bay

behind it are placed. When this is done, the pole holds the truss in position so that no guys are necessary on the truss. When all the steel framing between the two trusses is in place, the gin pole is moved and the operation is repeated.

Erection of Tall Buildings.—Tall buildings are almost always erected by means of guy derricks. The derrick must be first erected. This is an important operation and should be intrusted only to an experienced foreman. The erection of a guy derrick is described in another section of this book. It is always necessary to provide anchorages for the derrick guys. It is customary to embed hairpin anchors made of stout bar steel in the concrete of the foundation walls.

When unloading and storing steel the pieces should be placed on the ground with the numbered side visible, so that each piece can be found when wanted. The steel should never be placed in piles over two rows high, as it is difficult to find any member in a pile when the number is hidden. The work of sorting steel is greatly facilitated, if the detailed shop drawings are on hand, as beams can be recognized from the nature of the end connections shown on the drawings.

When the derrick is up and ready to be operated, the columns are first set in place, followed by the placing of girders and floor beams. The outlying girders are set first, the work gradually progressing around and closing in on the derrick. The columns and the floor framing for two floors are erected from each position of the derrick. When two floors are completed the derrick is raised, as described elsewhere in this book, to set the next tier of columns and the beams of the next two floors. This procedure is followed until the roof of the building is reached. The usual rate of progress in erecting the steelwork of buildings of this character is two floors per week, including the columns supporting them.

DRILLING MACHINES

There are several devices used for drilling holes in steel in the field. Among these are the air drill, the electric drill, and the ratchet drill. Where conditions will permit, a screw punch will give good results.

A twist drill for a drilling machine must have a shank that will fit in the machine. The air drill is usually designed for a round tapered shank. The ratchet drill is made for a square

tapered shank. The electric drill may be designed for either a round tapered shank or a straight shank. Adapters may be obtained that will permit shanks of either shape to be used. Twist drills with shanks of different shapes are shown in Fig. 202.

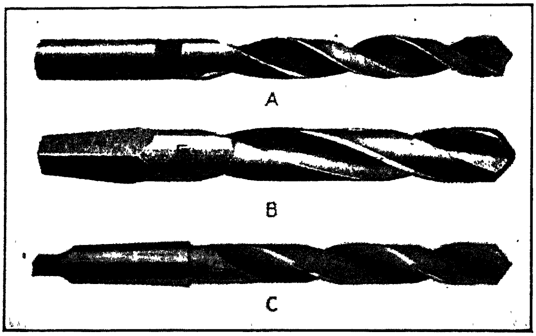


FIG. 202.—Twist drills.
a, round shank; *b*, square taper; *c*, round taper.

An air drill is better adapted to structural steel work than an electric drill, as it has more power and does faster work. It is also comparatively safe to operate. When a drill driven by an electric machine pierces the metal being drilled, the operator is subjected to a side thrust that may throw him, if he is sitting or standing on a plank above ground.

THREADING HOLES FOR SCREWS

It is frequently necessary to fasten pieces of metal together under conditions where rivets or through bolts cannot be used. Under such circumstances, machine screws or tap bolts screwed into threaded holes may be employed.

A hole is first drilled in the metal and is then threaded to receive the thread of the screw or bolt. The hole drilled for a machine screw should be large enough to provide a clearance for the metal at the base of the thread but not so large that only a scant depth of thread is obtained.

Machine bolts and screws are threaded in conformity with recognized standard threads of standard shape, and with a specified number of threads to the inch. The United States standard thread is the one in general use in construction work. The automobile trade and some other manufacturing lines make use of other standard threads.

After a hole has been drilled, a tap is inserted in the hole and rotated until a satisfactory thread has been cut in the side of the

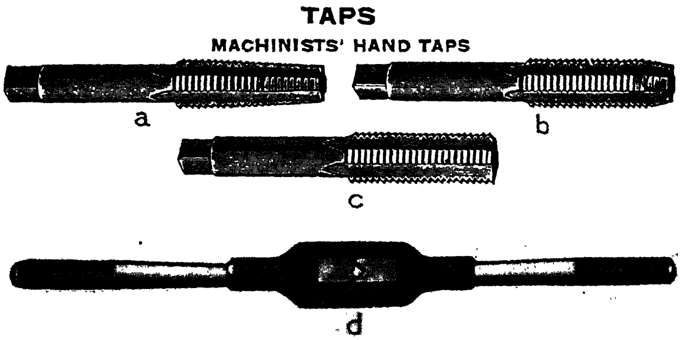


FIG. 203.—Taps and tap wrench.
a, taper; *b*, plug; *c*, bottoming; *d*, tap wrench.

hole. Figure 203 shows a standard hand tap with tap wrench for turning it. Table 8 gives a list of tap sizes, number of threads to the inch, United States standard, and the correct diameter of the drill to be used for each tap. In purchasing tap drills care should be exercised to specify the correct shape of shank as the various machines for drilling holes take shanks of different shapes.

A bolt inserted in an ordinary nut, which has only one-half of a full depth of thread, will break before stripping the thread. Also a full depth of thread, while very difficult to obtain, is only about 5 per cent stronger than a 75 per cent depth. Extreme nicety, therefore, in selecting a drill which will permit a full depth of thread is not necessary.

PIVOTED STEEL SASH

Sash.—Steel sashes have many advantages over the old-style wooden sash used in industrial buildings. They are fireproof and of stronger construction. They are fabricated as units and may be readily assembled in various combinations in the formation of large windows.

The small steel sections forming the muntins interfere very little with the entrance of light. Ventilation is usually obtained by opening pivoted portions of the frame. This feature provides a convenience far superior to vertically sliding sashes for large windows.

Pivoted steel sashes are made in standard units to take lights of glass of various sizes. The units of the same size are made interchangeable. Complete steel sashes may be had in stock sizes varying from a sash which is one light high and three lights wide to a sash which is seven lights high and six lights wide.

TABLE 8.—MACHINIST'S HAND TAPS AND TAP DRILLS
(United States Standard Threads)

Diameter of tap, inches	Number of threads to inch	Diameter of tap drill, inches
1/4	20	3/16
5/16	18	1/4
3/8	16	5/16
7/16	14	23/64
1/2	13	13/32
9/16	12	15/32
5/8	11	17/32
3/4	10	5/8
7/8	9	3/4
1	8	27/32
1 1/8	7	31/32
1 1/4	7	1 3/32
1 3/8	6	1 3/16
1 1/2	6	1 5/8
1 5/8	5 1/2	1 27/64
1 3/4	5	1 1/2
1 7/8	5	1 5/8
2	4 1/2	1 23/32

As many sashes as desired may be combined in continuous rows by joining adjacent sashes by means of steel mullions. The sashes may contain ventilators or not, as may be desired. The ventilators are arranged to swing inward at the top and outward at the bottom and may be fastened with a stay bar or with a spring catch, as desired. Whole groups of sashes may be arranged to be operated simultaneously by operating mechanism.

The glass used in steel sash should be at least "double thick" and may be 1/4 inch thick, if preferred. Several standard sizes

of glass are employed, the 14-by-20 size being most popular. The glass should be set in special steel-sash putty. Steel-sash putty is very slow in drying. It remains soft for months and will not dry out and crack like ordinary putty. It should not be put on in freezing weather.

The glazing is done from the inside. The glass should be carefully laid in a bed of putty. The spring-wire glazing clips should be inserted in the holes along the muntins and snapped in place so that the short bent portion slips over the edge of the glass. Putty should be then applied on the inside along the edge of the glass and given a bevel. In computing the quantity of putty required, allow 1 pound of putty for each light of 14-by-20 glass.

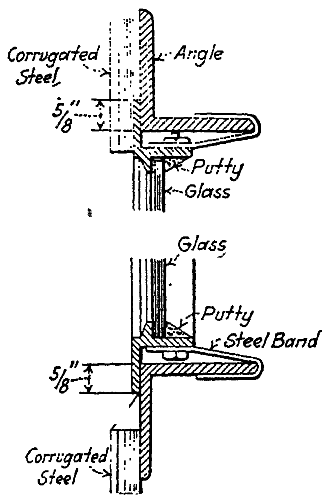


FIG. 204.—Section through head and sill of a steel sash in steel-frame building.

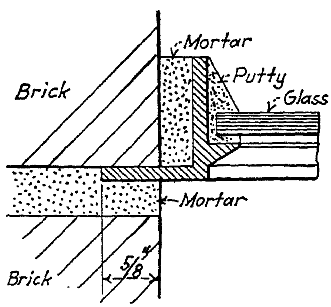


FIG. 205.—Jamb detail in brick wall.

Erection.—Steel sashes are usually erected by the carpenters on the job. The sashes must be placed plumb in both directions and should be stayed by wooden braces so as to remain in a plumb position. The braces may be fastened to the sashes by wooden clamps in any way that may be convenient. Care must be taken in setting the sashes to set them all right end up. This may be checked by noting that all ventilators open inward at the top.

Where more than one steel sash is placed in an opening, it is important to make sure that the top and bottom of the sashes are in line lengthwise with the wall.

Steel sashes in brick walls should be placed in position and should be bricked in as the wall is built up. When the shipment of the sashes has been delayed and they are not on hand when the brickwork has advanced above the sills, a groove may be provided into which they may be inserted later. This is only

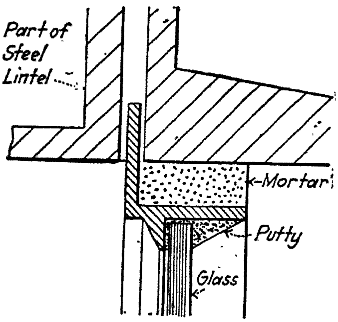


FIG. 206.—Head detail at lintel in brick wall.

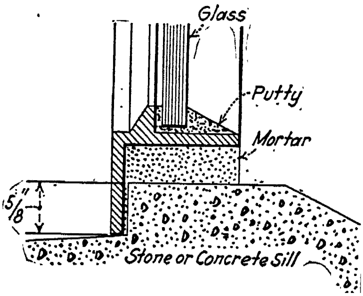


FIG. 207.—Sill detail in brick wall.

practical, as a rule, where sashes are joined by mullions. It is much more preferable to brick them in as the wall is built.

A typical section through the head and the sill of a steel sash in a steel building is shown in Fig. 204.

A typical detailed section through the jamb of a steel sash set in a brick wall is shown in Fig. 205. Sections through the head and sill are shown in Figs. 206 and 207.

CORRUGATED STEEL

Corrugated Sheets.—Corrugated steel is used for covering the exterior surfaces of roofs and sides of steel- and wooden-frame buildings. Standard lengths of sheets vary by 1 foot from 5 to 10 ft. long, inclusive. Sheets are manufactured with corrugations varying from 5/8 to 5 inches in width and from 3/16 to 7/8 inch in depth. The most popular sized corrugation has a width of 2 1/2 inches and a depth of 1/2 inch. The gages most frequently used for roofing are Nos. 20 and 22, U. S. standard gage. The gage. most frequently used for the sides of buildings are Nos. 22 and 24, Sheets of these sizes have a standard covering width of 24 inches when laid with a lap of one or one and one-half corrugations.

Supports for corrugated steel sheets should not be spaced over 5 feet apart as their capacity to support a load, when acting as a beam with a span over this distance, is greatly decreased below practical limits. Corrugated sheets should preferably span two spaces between supports. Steel for flashings and cornices should not be lighter than No. 20 gage. Corrugated sheets may be had with black or galvanized surfaces. Ordinary paint is apt to peel off galvanized surfaces in spots. For this reason, the first coat applied over the galvanizing should be a special priming paint made for the purpose. A priming paint of this kind is made by the majority of paint manufacturers.

Corrugated-steel sheets are usually laid directly on steel-roof purlins or against the steel girts forming the side framing. Sheets when laid on a roof should be given a side lap of one and one-half corrugations and an end lap of 6 inches (see Fig. 208). In sidings, the sheets may be given a side lap of one corrugation and a 4-inch end lap. If the sheets are to be laid with one corrugation lap in the siding and one and one-half corrugations lap in the roof, both edges of a siding sheet will be bent the same way and the edges of a roofing sheet will be bent in opposite directions. With 2½-inch corrugations the siding sheets can have a width of 26 inches and roofing sheets a width of 27½ inches.

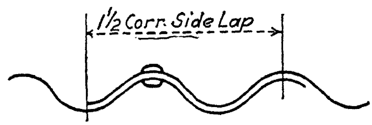


FIG. 208.—Side lap corrugated steel.

The edges of sheets along the side laps should be fastened together by either copper or galvanized-iron rivets spaced 8 inches apart on the roof sheets and about 12 inches apart on siding sheets. Copper rivets are preferable. Closing rivets $\frac{3}{16}$ inches in diameter are commonly used. In computing the length of the rivet required, a length about equal to twice the diameter

TABLE 9.—COPPER CLOSING RIVETS, $\frac{3}{16}$ INCH IN DIAMETER

Length, inches	Number per pound
⅜	200
½	170
⅝	140
¾	125

should be added to the grip as an allowance for the formation of a head. Where the corners of three or four sheets lap, rivets of extra length will be required. Stove bolts can be used at those points also. Table 9 gives lengths and weights of closing rivets $\frac{3}{16}$ inches in diameter.

There are several methods of fastening corrugated steel directly to steel purlins or girts. The most-popular methods of securing the sheets are by means of steel straps, iron clinch nails, and crimped-steel clips (Fig. 209). The effectiveness of these fastenings can be rated in the order named. The steel straps are the most dependable and are the preferable fastening for the roof sheets. Clinch rivets are the most popular type of fastening as they are quickly and easily placed.

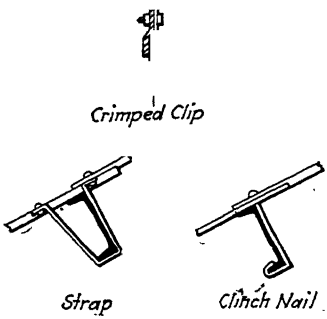


FIG. 209.—Fastenings for corrugated steel.

Clinch rivets, straps, and other fastenings of corrugated steel sheets to roof purlins and side girts should be spaced about 1 foot apart.

Straps.—Straps are made of thin steel, $\frac{3}{4}$ inch in width; No. 18 gage is a suitable thickness. The straps are bent closely around the steel purlins or girts, each end being secured to the corrugated metal with a small rivet $\frac{3}{16}$ inch in diameter. The straps are preferably cut and bent on the job to fit the shape of the steel member. A strap is shown in Fig. 209.

Clinch Nails.—Clinch nails are made of No. 10 annealed-iron wire and are galvanized to prevent rusting. One style of clinch nail is equipped with a head formed of lead. The required length of the clinch nail is determined from the size and shape of the steel member over which it is clinched. A clinch nail is shown in Fig. 209.

Sharp Point Square End

FIG. 210.—Spuds.

Crimped Clips.—Clips are mainly used where the other forms of fastenings are not practical to apply. Clips (Fig. 209) preferably should not be used on roofs. Clips should be about $1\frac{1}{2}$ inches in width by $2\frac{1}{2}$ inches in length and fabricated from No. 16

gage steel. They are crimped with a slight offset so as to fit smoothly over the thickness of a flange or leg of an angle as the case may be. They should be secured by stove bolts $\frac{3}{16}$ inch in diameter by 1 inch in length.

Punching Sheets.—The punching of holes for rivets and bolts is usually done with a sharp-pointed spud (Fig. 210) and a machinist's hammer. A spud makes a ragged hole with jagged pieces of metal standing up around the perimeter of the hole. A better job may be done by using a punch similar to the spud but having a square end, as shown Fig. 210. An end with this shape cuts the metal out cleanly and leaves the hole in better shape for riveting.

Usually, all punching of sheets is done in place. The punching should always be done from the outside of the sheet and through the high part of the corrugations so as to shed water properly.

Cutting Sheets.—Corrugated sheets may be cut by means of rotating shears, or, as is usually the case, by means of a cold chisel and hammer. When cutting with a cold chisel, to avoid deformation of the corrugations, the sheet should be laid upon a flat piece of steel and the bottom part of the corrugations cut. The sheet should then be turned over and the remainder of the corrugation cut in the same way.

Riveting.—The tools required for riveting are a machinist's hammer, a rivet set, and a small tool for use as a dolly bar. These tools can be best made on the job. A piece of bar steel can be made into a combined rivet set and header by drilling a hole and forming a cup in the end to take the head of the rivet. The dolly bar can be similarly fashioned or a heavy hammer can be used on small jobs.

The rivet is inserted in the hole and pressed home with the dolly bar. The set is placed over the rivet and struck with the hammer to consolidate the several thicknesses of metal. The end of the rivet is then struck with the hammer sufficiently to flatten it out and secure the sheets. The formation of the rivet head is then completed by applying the rivet header and striking it with the hammer.

Erection.—In applying corrugated sheets to the roof or sides of a building, it is necessary for the sake of appearance that the sheets be put on in an orderly manner. The sheets should be laid so that the exposed edges of the ends will extend in a straight line along the building.

In laying the sheets on a roof, the first course of sheets at the eaves should be laid first. The end of the roof at which the first sheet is laid, should be selected so that the prevailing strong winds of the locality will blow over the side laps and not under them. This is very important. A roof laid with sheets lapping the wrong way will rattle loudly when blown on by a strong wind.

In laying the first sheets, a line should be stretched along the line of the eaves as a guide for placing them. The first sheet should then be placed in position, giving it the correct overhang at the eave and at the gable. The eave overhang will usually be about 9 inches and the gable overhang much less, commonly about one or two corrugations.

The remaining sheets of the first course should be laid next. Care should be exercised to see that the corrugations of adjacent sheets in the same line fit exactly, as there is always a tendency for one end of a sheet to creep ahead of the other end. The edges of sheets at the side laps should always be aligned in a vertical direction so that the side laps will be parallel. Marks to assist in getting the sheets laid to line should be made on the steel of the building frame. If the sheets are not kept in alignment and fitted well into the corrugations of the adjacent sheets, the appearance of the work will be spoiled.

CHAPTER VIII

ROOFING AND FLASHING

Tar Roofing.—Tarred roofing materials provide a means of constructing a durable and inexpensive roof covering, but they are not suitable for slopes over 2 inches to the foot on account of the tendency of the pitch to flow in warm weather. A tarred roof covering consists of three, four, or five piles of tarred felt mopped thoroughly between plies with hot pitch. The entire roof area is finally finished with a protective covering of slag or gravel spread in a coating of hot pitch.

Tarred felt roofing may be applied in different thicknesses to suit the requirements in each case. The variations in thickness are obtained by using a different number of plies or layers of felt. A satisfactory roof covering may usually be obtained by using either a three- four-, or a five-ply thickness.

For application over concrete, a three- or a four-ply roofing is suitable. The roof should have a slope which does not exceed 1 inch to the foot. For application over boards either a four- or a five-ply roof should be used. The slope of the roof should not exceed 2 inches to the foot.

A four-ply roof is the standard covering recommended for use over concrete.

A five-ply roof is the standard covering recommended for use over boards.

Preparation of Roof.—Before the tar roofing is applied, the roof, whether or not of concrete, boards, or other material, should be prepared to receive the covering. All rough spots should be made smooth, all ridges or projections leveled off, and all depressions or holes filled. The surface of the roof should be neatly graded toward the conductor-pipe outlets and, where parapet walls, gutters, or valleys exist, suitable crickets should be formed to lead the water to the outlets.

A cricket is formed on a flat concrete roof by a filling of cinder concrete. The surface of the cricket should be given a slope of ⅛ to ¼ inch per foot. The thickness will vary from nothing at

the conductor pipe outlets to 4 inches or more at the parapet walls, depending upon the distance to which the slope is extended. The surface of the cricket should be finished with a mortar made of cement and sand and should be given an even surface with a wooden float. The roof slab need not be floated or troweled smooth if it is to be covered with cricket concrete. Where the slope meets the parapet walls the cricket concrete should be

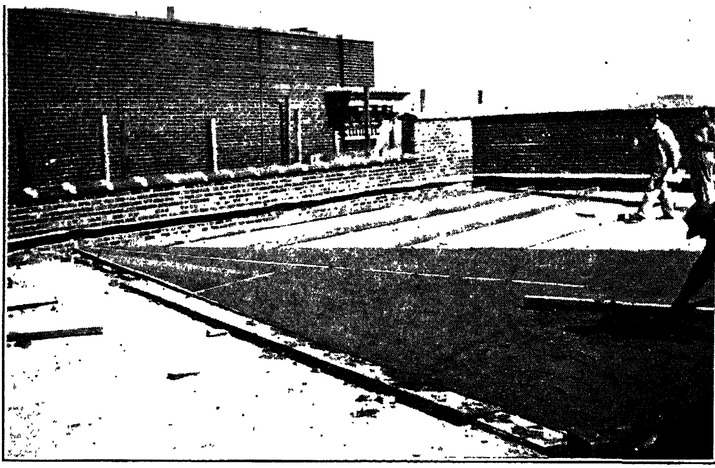


FIG. 211.—Placing roof cricket.

beveled in the corner. Roof crickets are shown in Figs. 211 and 218.

The following descriptions of three-, four-, and five-ply roofs are according to standard specifications.

Three-ply Roof.—A three-ply roof is designed for use over concrete or similar material where the slope does not exceed 1 inch to the foot. A three-ply roof is formed of three plies of roofing felt mopped thoroughly between plies with hot pitch.

Roofing felt is made with a width of 32 inches. In detail, the roof is built as follows: Over the entire surface lay three plies of felt, setting the edge of each sheet 10 inches back from the corresponding edge of the preceding sheet; this gives a lap of 22 inches over the preceding one. The entire surface under each sheet should be covered uniformly with hot pitch, the lap of 22 inches on each sheet being thoroughly coated with pitch so that felt cannot touch felt.

As the edge of each sheet is placed 10 inches back of the corresponding edge of the adjacent sheets and as the width of the felt is 32 inches, it will be seen that an additional 2 inches of width remains to insure the lapping of sheets. When the entire surface, both concrete and felt, under each sheet has been mopped, the surface of the roof has been covered in this way with a uniform coating of pitch.

Then, over the entire surface of the three ply already laid, pour a uniform coating of pitch into which, while still hot, embed not less than 400 pounds of gravel or 300 pounds of slag for each 100 square feet of surface. The gravel or slag should be formed of particles from 1/4 to 5/8 inch in diameter and should be dry and free from dirt. Not less than 175 pounds total of pitch should be used for constructing each 100 square feet of completed roof.

Four-ply Roof.—The application of four-ply roof covering over concrete and over boards requires different processes.

When applied over concrete, a four-ply roof is formed of four plies of felt mopped thoroughly between plies with hot pitch. In detail the roof is constructed as follows: Over the entire area of the roof, lay four plies of roofing felt, setting the edge of each sheet 7½ inches back from the edge of the preceding sheet, which gives a lap of 24½ inches over the preceding one. The entire area under each sheet is mopped with hot pitch, the lap of 24½ inches on each sheet being mopped so that at no place does felt touch felt. The entire surface of the concrete is covered in this way with a uniform coating of pitch.

After the four plies of felt are laid, the pitch-and-gravel covering is applied as described under three-ply roofing. Not less than 200 pounds total of pitch should be used for constructing each 100 square feet of completed roof.

When applied over boards, a four-ply roof is formed of one layer of sheathing paper laid dry, two plies of felt laid dry, and two plies of felt mopped between plies with hot pitch.

The boards should be first covered with one thickness of sheathing paper or unsaturated felt, laid dry, lapping the sheets 1 inch. Two plies of roofing felt, laid dry, should then be placed over the entire surface, setting the edge of each sheet 15 inches back from the corresponding edge of the preceding sheet, giving a lap of 17 inches over the preceding one. The dry sheets may be nailed as often as necessary to secure the sheets in place until

the remaining felt is laid. The nailing should be done so that the nails are covered by at least one ply of felt. This may be accomplished by locating the nails about 6 inches from the upper edge of the sheet.

Two piles of roofing felt are then laid over the entire surface setting the edge of each sheet 15 inches back from the edge of the preceding sheet thus giving a lap of 17 inches over the preceding one. The entire area under each sheet is thoroughly mopped with hot pitch, the lap of 17 inches being mopped so that felt does not touch felt. The entire surface of the two-ply dry roofing is covered in this way with a uniform coating of hot pitch.

After the four plies of roofing felt have been laid as described, a coating of hot pitch and gravel or slag is applied as specified for three-ply roofing. Not less than 125 pounds total of pitch should be used for constructing each 100 square feet of completed roof.

Five-ply Roofing.—A five-ply roof is designed for use over board sheeting. It is formed of one layer of sheathing paper laid dry, two plies of roofing felt laid dry and three plies of roofing felt mopped between plies.

One thickness of sheathing paper or unsaturated felt is laid over the boards, lapping the sheets 1 inch. Two plies of roofing felt are then laid dry over the sheathing paper, setting the edge of each sheet back 15 inches from the edge of the preceding sheet, which gives a lap of 17 inches over the preceding one. The sheets are nailed as often as is necessary to secure them in place.

Over the surface of the roof, apply three additional plies of roofing felt, setting the edge of each sheet 10 inches back from the edge of the preceding sheet. This gives a lap of 22 inches over the preceding one. The entire surface under each sheet of the three plies should be thoroughly mopped with hot pitch, the lap of 22 inches being covered with pitch so that felt does not touch felt. The entire surface of the two-ply dry roofing is covered in this way with a uniform coating of pitch. All nailing should be done so that the nails are covered with two plies of felt.

The entire surface should then be covered with hot pitch and gravel or slag as described for three-ply roofing. Not less than 150 pounds total of pitch shall be used for constructing each 100 square feet of completed roof.

Flashing Reinforcement.—Where a roof covered with tar roofing, intersects a vertical surface, it is necessary to provide some sort of flashing or flashing reinforcement in the angle

formed by the two surfaces. This is especially true along the angles formed by a roof and parapet walls where gutters leading to conductor pipes are formed. The roofing in these angles should have a thickness equal, if not more than equal, to the remainder of the roof. Several additional plies of felt are usually set in, so that the entrance of water will be prevented.

A standard method (Fig. 212) of laying tar roofing at the angles of a parapet wall, where a metal base flashing is not used, is that of turning the first two plies of roofing up against the wall. This is done by turning the end of the sheets up the wall about 6

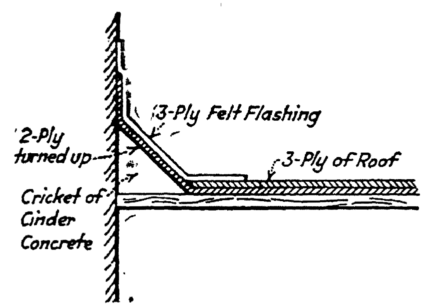


FIG. 212.—Flashing of roofing felt only. Juncture of roof and vertical surface.

inches and by folding the sheets so as to turn up the walls which run parallel to the edges. The remaining plies of felt are usually cut off at the angle, as shown in Fig. 212. An additional reinforcement of at least two plies of felt is then set in the angle lapping the edges of the sheets in such a manner as to prevent the entrance of water. As indicated in the figure, the reinforcing plies should cover the edges of the roofing plies completely and be set in a thorough bedding of hot pitch.

Where a metal base flashing is used a similar procedure is followed (see Fig. 213). The base flashing should be nailed at the top edge with copper nails driven into wooden plugs set about 18 inches apart in the brick walls. The bottom edge of the base flashing should be nailed every 6 inches into the roofing. The base flashing should be installed above the roofing plies and felt flashing reinforcement. Two additional plies of felt each one-half a sheet in width should than be laid in hot pitch over the lower edge of the base flashing so as to cover the nails and prevent leakage. These additional plies of felt should extend from the roof to the angle of the base flashing.

Tar and Gravel Roofing.—Tarred roofing felt is furnished in standard rolls containing 432 square feet of felt. The felt is made with a standard width of 32 inches.

Roofing pitch is furnished in barrels. A standard-sized barrel of pitch weighs approximately 325 pounds.

A thick plastic roofing cement may be obtained, which will be found very useful in setting flashing reinforcement in the vicinity

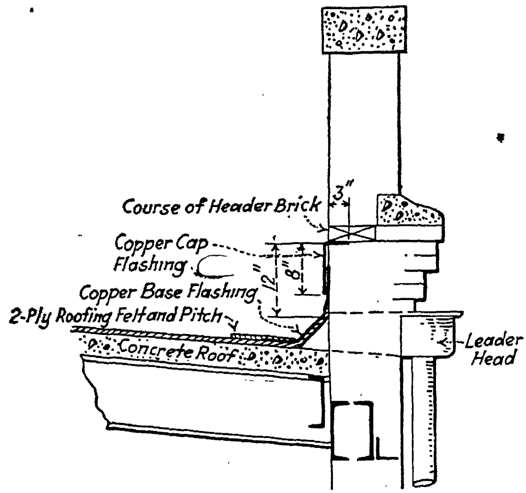


FIG. 213.—Detail showing cap and base flashing.

of gutters and around ventilators and other objects projecting above the roof surface. The cement remains plastic at all ordinary temperatures and can be most conveniently applied with a small trowel. It may be obtained by the barrel or fraction of a barrel.

ROOFER'S EQUIPMENT

The following is a list of equipment useful in laying tar and gravel roofing:

Tar kettle
Galvanized iron pails
Dippers
Axe
Improvised wooden gravel pusher
Pulley wheel or single tackle block

Rope
Mop handles and mop yarns
Bags for handling slag
Broom
Shovel

Laying the Roof.—A tar roofing gang usually consists of three or four men. One man is assigned to caring for the tar melting kettle. The roofer lays the roof with the assistance of one or two other men. One of these men applies the hot pitch with the mop as the roofer spreads the roofing felt, the other man being engaged in carrying the tar pails back and forth.

The laying of the roofing felt should be started at the low points of the roof such as at the eaves and along gutters. The felt should be laid several piles thick in starting, so that the correct thickness of plies will be obtained in the finished roof at that point.

After the starting sheets have been laid, the position of the edge of each following sheet should be marked on that previously laid. Care should be taken to keep the sheets of felt running parallel to each other and spaced with the correct lap. The sheets should preferably not be cut to length in advance. The felt is handled more easily in the roll.

The position of the edge of a lap having been marked out, the roll of felt is placed in position at one end of the roof and unrolled until the roll has arrived at a point about halfway across the roof. The edge of the felt is then placed along the marks to fix the direction in which it is to be laid. The free end of the felt is then rolled up toward the roll in the center, preparatory to mopping on the pitch. The main part of the roll serves to hold the felt steady in direction. The pitch is then applied starting at the roll and proceeding in the direction of the free end, the felt being unrolled and pressed with a broom into the coating of hot pitch as the latter is applied. When the free-end portion of the sheet has been laid, the roofer starts agains at the center, working in the opposite direction mopping on the pitch and unrolling the roll of felt as he proceeds. When the roll has reached the end of the roof, the sheet is cut from the roll.

The lapping of each sheet over the preceding one should be in accordance with the specifications for roofings of the various plies already described. All end laps of sheets should be not less

than 4 inches in width. All nailing should be done with ⅞- or 1-inch roofing nails, driven preferably through tin discs.

Roofing pitch is packed in solid form in barrels and must be broken into fragments small enough to be put into the tar heater. Care must be taken in melting the pitch not to heat it to too high a temperature as the whole melted contents of the heater is likely to take fire. The tar heater should be located on the ground, the melted pitch being dipped from it with a dipper and poured into pails which are hoisted to the roof. On tall buildings the heater should be placed on the roof, taking care to elevate it off the tarred roofing sufficiently to prevent any damage being done.

The hot pitch should be applied with a roofer's mop. The roofer's mop consists of twine yarn bound to the end of a stick

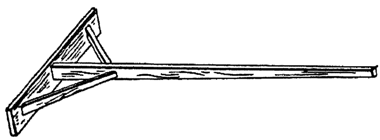


FIG. 214.—Improvised slag pusher.

about 5 feet long. The mops are inexpensive when bought by the dozen. Those used in roofing work wear out rapidly, a mop yarn frequently lasting only a half day in cold weather. The mop yarn may be bought in skeins, cut to length, and tied to the handles when replacement is necessary. Ordinary floor mops may be used to spread roofing pitch, but the yarn is too long and too fragile; the strands become broken and wear out quickly.

The gravel or slag coating of pitch should be poured on the roof so as to assure sufficient pitch for bedding the slag. The pitch is poured from a dipper or pail starting at the high point of the roof. The gravel or slag should be handled in bags and dumped in heaps on the roof deck so that it may be conveniently pushed into the hot pitch as it is poured. The slag may be pushed along by an improvised pusher such as shown in Fig. 214.

FLASHING

Flashing.—At various places on the roof of a building, it is necessary to insert strips of metal to guard against the entrance of rain water. These metal strips are called "flashings." They are required where the roofing material joins the vertical surface

of a brick wall, on walls under coping stones, and in many other locations depending upon the nature of the construction. The best material for this purpose is copper sheet metal, weighing 16 ounces to the square foot. Zinc and galvanized iron may be used also for flashing, but zinc is not as easy to work as copper and galvanized iron is quickly attacked by rust.

A typical example of a metal roof flashing used with tar-and-gravel roofing is shown in Fig. 213. By an inspection of the

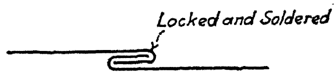


FIG. 215.—Locked seam.

figure, it will be seen that the flashing consists of two parts, the lower portion or base flashing and the upper portion or cap flashing. These two portions are sometimes described as the flashing and the counter flashing.

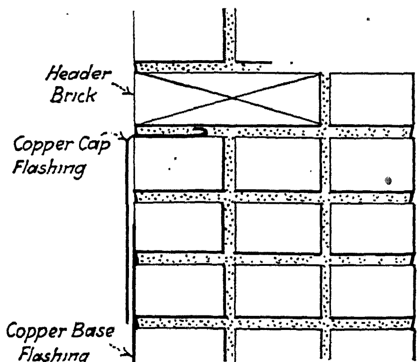


FIG. 216.—Correct method of cap flashing.

The base flashing will have to conform to the shape and length of the roof cricket. The copper sheeting should be ordered in sheets of standard lengths to avoid unnecessary joints as far as possible. Sheets of standard lengths and widths are carried in stock by the manufacturers. Joints where necessary should be made with a locked seam (Fig. 215) and soldered securely. The base flashing is customarily placed after all the plies of roofing felt are laid. The base flashing can be nailed into the vertical joints of the brickwork with steel nails or a better job may be done with it by nailing it with copper nails driven into

wooden plugs set in the brickwork about 18 inches on centers. The plugs should be driven into holes drilled in the brick masonry and cut off flush with the surface of the wall. The bottom edge of the base flashing is nailed into the roof. Two plies of felt laid in a thick bed of hot pitch may be placed over the bottom edge of the base flashing to seal the joint against the entrance of water.

The cap flashing is designed to prevent rain water from running down the surface of the wall behind the base flashing. Suitable

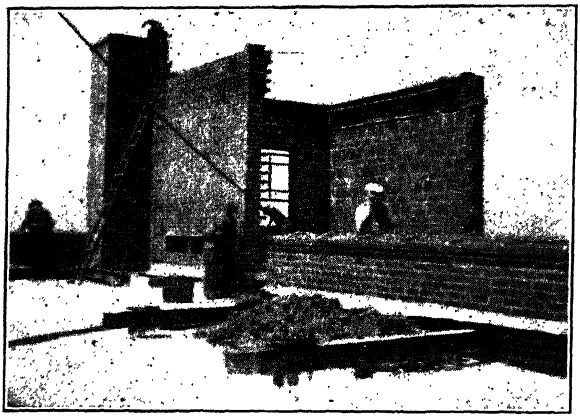


FIG. 217.—Cap flashing in place.

proportions for a cap flashing are given in Fig. 213. It will be noted that the cap flashing is bent at right angles and inserted into the brickwork 2 or 3 inches. It is common practice to insert cap flashing bent simply at right angles, as shown in Fig. 213. This, however, provides an opportunity for water to run down the wall and seep in along the upper surface of the cap flashing into the body of the wall.

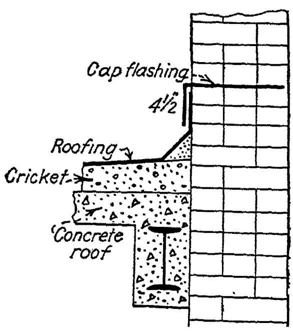


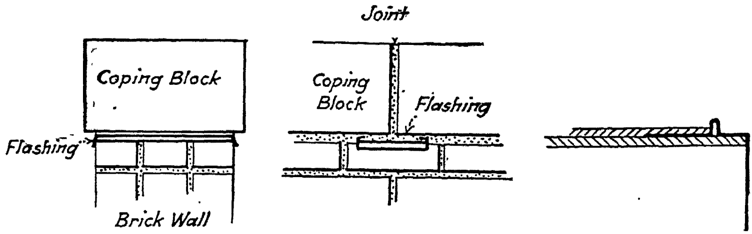
FIG. 218.—A cap flashing.

To make a first-class job of flashing, the cap flashing should be bent back upon itself at the edge inside the wall, as shown in Fig. 216. This effectively prevents the seepage of water into the wall and forces it to flow outward over the surface of the cap flashing. To hold the cap flashing securely in position, the course

of bricks, in the wall immediately above it, should be laid as a course of header bricks as shown in the figure.

Figure 218 represents another form of cap flashing. The importance of providing ample cap flashing cannot be overemphasized, as many leaks in buildings find a passage downward through the coping. The best possible arrangement is obtained when the cap flashing is extended clear through the wall.

Lead flashing should be used over limestone. Copper flashing is not suitable, as the corrosion of the copper will coat the limestone with a green stain. This stain is frequently discernable



Flashing under joints of coping blocks. Gravel stop.

FIG. 219.—Flashing and gravel stop.

on the cement joints of a terra cotta or stone cornice if it is covered with sheet copper.

Flashing under Coping Blocks.—The tops of brick walls should be protected from the infiltration of rain water down through the vertical joints between coping stones. Water seeping downward through these joints during rainstorms will eventually work a passage down through the wall below the roof line. This water seepage may be prevented by a strip of copper slightly wider than the wall placed under the coping and extending continuously the entire length of the wall. The edge of the metal should be bent downward over the wall to form a lip on each side. This method requires considerable copper sheeting and besides prevents a proper bonding of the mortar between the top of the brick wall and the bottom of the coping stone.

Another method of procedure is shown in Fig. 219. Small strips of sheet copper about 6 inches wide and with a length about 1 inch greater than the thickness of the wall are bent as represented in the figure. One of the strips should be placed so as to be located under each joint as the coping stones are set. It will be noted that each piece of flashing is bent so as to collect

any seepage through the joint and drain it to the outside of the wall.

Along the eaves of an inclined roof, it is necessary to provide strips of metal flashing fashioned in such a manner as to prevent the gravel and tar coating from working off the roof. Such metal strips are known as gravel stops. A gravel stop is shown in Fig. 219.

The projecting portion of the stop should be made about 1 inch high and may be placed at the exact corner of the roof edge or kept back 1 or 2 inches, as shown in the figure. Either way will

FIG. 220.—Applying roofing felt.

answer the purpose, but the shape shown in the figure is better in appearance.

The gravel stop should preferably be placed in position after several plies of roofing have been laid. Ordinarily, it is placed after the completion of the roofing. In any case, the edges of the gravel stop should be nailed to the roof deck and to the sides of the building with nails about 6 inches apart.

The edge of the stop on the roof should be covered by at least two plies of roofing felt set solidly in hot pitch. The completed roof exclusive of the gravel should come within about $\frac{1}{4}$ inch of the top of the projecting portion of the stop.

Soldering.—The work of soldering copper and other sheet metal flashings is full of difficulties to an inexperienced workman.

Since a great part of the work has to be performed in the open air and in cold weather, it is difficult to do. A plumber's furnace is necessary for this work to heat the soldering coppers. The furnace is made of sheet iron and burns charcoal. A blowtorch may be used to heat the smaller-sized soldering coppers but in the open on a windy day, a blowtorch becomes almost useless.

Several soldering coppers should be provided, those of 1-, 2-, and 4-pound weights being the most useful. The coppers of the heavier weights hold the heat the longest. There is a difference in the solder needed with different metals. Solder, known in the trade as "half and half," will prove suitable with sheet copper flashing.

The surfaces to be united must be clean and free from oxide, which would prevent adhesion and prevent the formation of an alloy between the solder and the metal. As the surfaces when heated are very easily oxidized, they must be protected from oxidization during the soldering operation. This is done by means of a flux which covers the surface and protects it from the air.

The fluxes which give the best results are chloride of zinc and rosin. Chloride of zinc may be easily made by immersing strips of zinc in muriatic acid. As the zinc is added, the acid effervesces and gradually loses its yellow color. It becomes clear and colorless. The resulting fluid is the desired flux. A small quantity of zinc is sufficient to "kill" the acid, as it is termed. A quantity of undissolved zinc should be allowed to remain in the solution to make sure that all the acid has been neutralized.

The soldering copper is heated in the furnace to the desired temperature. It should be cleaned and tinned on the end before an attempt is made to solder with it. A soldering copper can be most quickly cleaned by applying it while hot to a quantity of sal ammoniac. To do this in the most convenient way, a box-shaped copper container should be made, measuring about 4 inches on a side. A large piece of sal ammoniac should be placed in the container. The tip of the hot soldering copper is rubbed back and forth in the center of the chemical and quickly becomes clean and bright. Melted solder from the copper will gradually collect in the bottom of the hole worn in the crystal. The solder adheres to the copper as it becomes clean, and the cleaning and tinning are performed in one operation.

A soldering copper can be cleaned by inserting the tip in muriatic acid. A copper gradually becomes covered with scale

and is not easily cleaned. It should then be rubbed in sal ammoniac or cleaned with a file. A soldering copper may be considered clean when a tinning of solder will cover the tip of the tool.

Soldering coppers are always worked in pairs, one being heated in the furnace while the other is in use. They are sold in pairs, 8-pound soldering coppers weighing 4 pounds each. Coppers weighing 4 pounds each should be used on copper flashing work. They decrease in size by repeated cleanings during use.

The flux is spread over the surfaces to be joined. The surfaces are then tinned with a thin coating of solder. They are placed together and the hot soldering copper is then applied to them long enough to cause the solder to "sweat" along the joint. More solder can be applied along the edges of the seam wherever it is thought necessary. It should be borne in mind that the essential thing is to heat the metal rather than the solder. The metal should be heated hot enough to melt the solder. It is difficult to make solder adhere to cold metal.

When soldering sheet lead flashing, several precautions should be observed so that holes are not melted through the lead. The coppers should not be heated too hot. They should be small in size and should not have sharp tips. The tip should not be allowed to touch the sheet lead but should be applied very lightly to the solder. Rosin is the flux recommended for lead work, but prepared soldering pastes are more convenient to use.

CHAPTER IX

LATHING AND PLASTERING

Plaster may be applied directly to the surface of brick or hollow-tile walls and to the surface of concrete. It may be applied also to a supporting base of metal or wooden lath.

Outside work should be done with a portland-cement mortar having a slight proportion of lime added to it for the purpose of increasing its plasticity and spreading quality. There are various manufactured materials which may be added to a cement mortar which will render the plaster dampproof and at the same time give the plaster the same spreading quality.

Inside plastering work may be done with a gypsum or with a lime plaster. A plaster of portland-cement mortar, of course, may be used for inside work, where it is thought desirable, just as well as for outside work.

In beginning a discussion of plastering work, attention should be called to a marked change in the nature of materials used in interior plastering that has developed in a few recent years. Modern methods of plastering interior surfaces employ gypsum cement plasters for the brown coats and gaged lime plaster for the finishing coat. Previously, lime mortar was used for both the brown coats and for the finish coat. The use of lime mortar for the brown coats has become obsolete and it is seldom specified at the present time for important work.

Gypsum plasters have largely superseded lime plasters because the latter require several months to harden. During this period of hardening, a lime plaster remains damp and gives off moisture. A gypsum plaster hardens in about 2 hours after application and 1 or 2 days thereafter the wall is dry.

LATHING

Lath.—In the past, the only laths in use were wooden laths. Wooden laths are nailed to the studs of wooden-frame buildings, or to wooden furring strips nailed to the walls of brick buildings. Lath fabricated of steel is now in common use. At the present

time, while wooden laths are commonly used in small wooden-frame buildings, metal lath is used in all the better-class buildings. The interior surface of the walls of brick buildings of first-class construction is frequently covered with metal lath fastened to metal furring strips, which are in turn secured to the brick walls by metal wall plugs inserted in the joints of the brickwork (see Fig. 221).

Wood Lath.—Wood plastering laths are usually of sawed spruce 1½ inches wide, ⅜ inch thick, and 4 feet long. They should be straight grained, seasoned and free from bark and live knots,

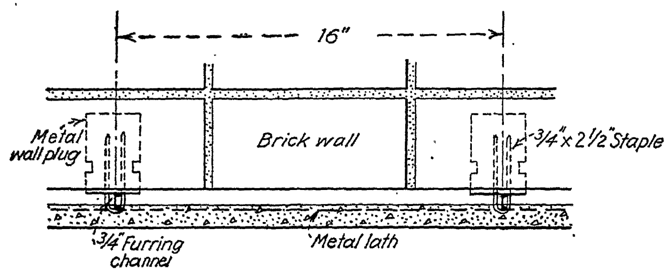


Fig. 221.—Steel furring.

as the latter are apt to stain the plaster. The length of a lath fixes the spacing of studs, furring strips, and floor joists. Laths are nailed horizontally on walls in parallel rows, with their edges not less than ⅜ inches apart so that the mortar may be pressed through. The mortar coiling downward over the edge of each lath forms a key which clinches the mortar to the lath base. If the laths are laid too close together, sufficient mortar cannot be pressed between them to form a proper clinch on the back. On the other hand, if the laths are spaced too far apart, the mortar is inclined to drop out from between them while still soft.

Laths are laid with end joints meeting on the supports. Ends of laths should not be permitted to butt or overlap. Continuous joints should not occur on one support. The surface should be divided into panels, the panels breaking joins on alternate supports every eight or ten laths to avoid cracks due to shrinkage. Laths over openings should not break joints along the line of the sides of the openings. This precaution is necessary to avoid cracks in the plaster at such locations. Laths are secured to furring, studs, and joists by three-penny nails with large heads.

One nail should be used at each end of the lath and one nail at each intermediate stud.

Laths are cut and nailed with a small lathing hatchet. All cutting of laths is done after they have been nailed in place. Lathing nails are usually held in the lather's mouth from which they are taken one at a time and driven into the lath with one blow of the hatchet. Lathing nails are made of blued steel and are thoroughly cleaned at the factory. The kegs in which they are shipped are lined with paper as a further precaution to the lather.

Lathing is measured by the square yard. Wooden lath are sold by the thousand in bundles containing 100 lath. It requires about 1500 lath and 10 pounds of lath nails to lath 100 square yards of surface.

Wooden lath should be thoroughly wet with water ahead of the plastering so as to dampen them and permit them to swell before the plaster is applied. The chief troubles experienced from wooden lath are caused by expansion, contraction, twisting, and buckling of the lath. To safeguard the plaster against defects in lathing, care should be exercised to see that at least 3/8 inch is maintained between the ends of laths and an equal distance between adjacent edges.

Laths that swell and buckle exert a considerable pressure which shears off the mortar keys and loosens the plaster from the laths. Cracks which develop in plastered surfaces following the direction of the laths are due to buckling lath. The plaster in such cases usually bulges out along the crack, and the wall has a hollow sound when tapped.

Metal Lath.—Metal lath is usually either some form of expanded metal or woven-wire mesh. Expanded metal lath is furnished in standard lengths of 8 feet. The width varies from 14 to 24 inches and to greater widths. Expanded metal lath should not be lighter than No. 27 United States gage. Woven-wire lath may be had in all widths from 1 up to 10 feet and is furnished in long rolls of 100 to 200 feet. Wire lath should not be lighter than No. 20 United States gage. Metal lath should preferably be galvanized, but it is frequently painted.

Expanded metal lath should always be applied witn the sheets running horizontally. The sheet should be turned so that the holes in the mesh point downward and so that the mortar clinches will point in that direction. Sheets should be lapped 1 inch; too great a lap permits movement of the mesh and should

be avoided. The laps should be securely fastened with No. 18 United States gage, galvanized, annealed-iron wire. The ties should be spaced every 6 inches. Sheets should be put on the walls starting at the bottom, lapping the sheets shingle fashion. The top sheet laps over the one below it. If the sheets are lapped the other way, the weight of the soft mortar will cause the top edge of the lower sheet to sag and bulge outward. The sheets can be laid either way, however, provided they are wired and fastened at close enough intervals. There should be a tie along the horizontal laps at each stud or furring strip and, always, a tie between them to hold the lap secure and prevent sagging.

Metal lath laid over wooden studs or wooden furring strips is usually nailed to them with galvanized roofing nails. The nails are 1 inch long and have flat heads measuring ½ inch in diameter. Metal lathers cut the tie wire in lengths of about 2 feet and hang these on their belts where they are conveniently accessible. When tying the lath with wire, it is usual to bend the end of the wire into a hair pin shape and then into a hook and to tie the lath with the wire doubled. The wire is tied with a double twist, cut with pliers, and is then bent back flat against the lath.

Furring.—Furring may consist of strips of wood or small steel structural shapes fastened to the walls or ceilings of brick or wooden-frame buildings.

Wood Furring.—Wood furring consists of strips of softwood usually ⅞ by 2 inches in cross-section, surfaced on one side. Furring is utilized to straighten surfaces intended for plastering and to form a base for the lathing. Furring strips are spaced either 16 or 12 inches on centers to conform to the length of wooden laths which are 4 feet long. Furring strips on brick walls are placed vertically and secured to the brick walls by nails driven through the strip and into the mortar joints of the brick masonry. Wooden plaster laths make excellent nailing strips for wooden furring. The lath should be inserted in the joints of the brickwork at 2-feet intervals measured vertically. Cut nails can be used to nail the furring to the strips, as the wedging action of the cut nail gives pronounced holding power. Where wooden furring is nailed directly into the mortar joints, it is preferable to use case-hardened cut nails, particularly where the mortar is hard.

Ceilings are furred by running the furring strips crosswise on the floor joists and by nailing them securely to the underside

of each joist with ten-penny nails. The object of furring ceilings is that of obtaining a straight plastered surface and that of correcting any difference in level in the bottom of the joists. A great advantage in furring a ceiling lies in the fact that the floor joists may be given any odd spacing desirable, instead of being spaced 16 inches to conform to lath lengths. The furring is spaced 12 or 16 inches on centers. The furring strips are brought to an even surface by working from leveled furring strips extending around the sides of the ceiling adjacent to the walls.

Steel Furring.—Steel furring consists usually of ¾-inch channels (see Fig. 221). Steel furring should be galvanized or painted. They are placed vertically with a spacing of either 16 or 12 inches. They may be best secured to brick and tile walls by means of galvanized staples driven into galvanized-metal wall plugs inserted in the mortar joints of the wall. Wall plugs are set by the bricklayer when building the wall. They should be spaced vertically about 2 feet apart.

If exterior brick walls are to be plastered on the inside they should be furred. A brick wall absorbs moisture readily and if the plaster is applied directly on the brick, the moisture will penetrate through the plaster and make the wall damp. Figure 221 shows a horizontal section through a brick wall furred with ¾-inch channels and covered with metal lath. As will be seen by an inspection of the figure, the furring forms an air space between the plaster and the wall which is effective in blocking the passage of moisture.

Grounds.—Grounds are formed by strips of softwood surfaced to a uniform thickness. They are placed around all openings and along the bottom of the walls near the floor (see Fig. 222). They are installed for the purpose of acting as a guide in bringing the plaster to an even surface. They act, also, as a stop against which the plaster is finished and form a convenient means of fastening the inside finish to the walls. The grounds should be kept back ½ inch from the edge of all finish. One or two grounds should be nailed along the bottom of the wall to which the base may be nailed and a border nailed around all window and door openings. Special wooden plaster casings or "ground casings," as they are often called, may be used at openings in place of the ordinary grounds.

Grounds have to be put on very carefully. It is necessary that the base grounds be level and at the correct distance above

the floor line so as to maintain the correct position relative to the top of the base.

It is also necessary to run the grounds straight and true, as viewed in plan, for they are used as guides by which the plaster is made straight and because they must fit with the base. In installing the grounds on brick walls with metal furring, marks are made on the walls locating the position of the top edge. This should be about ½ inch below the top of the base. A chalk line should then be stretched along the wall, about 1 inch out from the desired position of the face of the ground. The ground can then be nailed to the wall, measuring back from the chalk line and blocking it out with wedges, where necessary, to bring it into position. In frame buildings the grounds are nailed to the studding. Where steel furring is used on brick or tile walls, the base grounds are nailed into the mortar joints and short supporting legs are cut into the space below them. These are called soldier grounds. Specifications frequently call for soldier grounds at all joints in the base but they are usually unnecessary. The bottom ground should be placed just above the floor. The top ground will usually be in the correct position, if the center of it is located at the same height as the joint between base and base molding. The top of the ground should be kept below the top of the molding. Where the walls are furred with wood furring strips, the grounds are nailed to the furring.

Grounds should be set flush with the intended face of the plaster. The thickness of ground required will vary with the number of coats of plaster and with the nature of the surface on which the plaster is applied. Three-coat plaster is usually necessary on lath and exterior walls, two-coat plaster is usually employed on interior tile and brick partition walls. The sizes of grounds commonly employed are as follows:

	Thickness, Inches
On wood lath, three-coat work	⅞
On metal lath, three-coat work	⅝
On brick and hollow tile, two-coat work	½
On gypsum blocks	½

PLASTERING

Materials.—The materials entering into the composition of plastering mortars intended for interior work are: lime, gypsum

cement, sand, either fiber or hair, and plaster of paris. Cement mortars, tempered with a small proportion of hydrated lime, are used for both interior and exterior work.

Sand.—Sand for a plastering mortar should be fine grained and should be screened to the desired fineness. A No. 6 screen is suitable. The greater the proportion of sand in the mortar the less the plaster will shrink. Sand should be clean and free from all traces of clay or loam. The grains should be sharp and angular. For these reasons, screened pit sand is considered the best for making plastering mortar. Sea and river sand are composed of rounded particles and while used in some sections of the country for plastering are not as desirable as the bank sand.

Lime.—Lime is made by heating limestone to a red glow, expelling in this way the carbonic acid and water. The resulting white product is called quick lime. Lime comes from the kiln in lumps and is then marketed under the trade name of lump lime. Lump lime is shipped in wooden barrels of 180 and 280 pounds, net weight. Fresh lime is in hard lumps mixed with a small quantity of powder. Lime which has deteriorated by exposure to the air consists mainly of powder and small lumps which are soft and crumble easily.

The quick lime must be reduced to lime paste before being mixed with the sand to form a mortar. This is done by slaking the lime. The quick lime is placed in a wooden slaking box and a quantity of water is sprayed upon it. The water is absorbed by the lime and a chemical action takes place, generating heat and steam. This causes the lime to swell to about two and a half times its original bulk, the individual lumps bursting open and turning into a powder at first and later into a paste. This process is called "slaking" and the product when cool is called slaked lime or lime paste.

In all quick lime, there are particles that resist slaking. If these were to find their way into a plaster wall unslaked, they would slake later in the wall, swelling and pitting the surface as they drop from it. For this reason, the slaked lime should be stored for several days, until thoroughly slaked and cool, before it can be considered fit for use in the plaster. One part of quick lime will make two and one-half parts of lime paste.

Hydrated Lime.—Hydrated lime is the name given to slaked lime which has been slaked at the place of manufacture before shipment. It is sold in powdered form and it is packed in bags.

This form of lime is very popular as, having been slaked at the mill, it is very convenient to use. There are two varieties of hydrated lime: one, intended for bricklaying and similar purposes, is known as mason's lime; the other, intended for the white finish coat on plastered surfaces, is known as finishing lime. The finishing lime is pure snow white in color and composed of very fine particles. Masons' lime is not so fine and has a gray-white color.

Hydrated finishing lime when used for plastering should be made into paste a day or more ahead of time and allowed to stand so that thorough slaking is assured. The working qualities under the trowel are thus improved. Hydrated lime is packed in cloth sacks weighing 100 pounds and in paper sacks of 50 pounds. One cubic foot of hydrated lime weighs 40 pounds, a 50-pound sack makes a trifle over 1 cubic foot of paste.

Hair and Fiber.—Hair used in plastering is obtained from the hides of cattle and is mixed into the mortar with the object of binding it together and of rendering it more tenacious. Fiber or hair holds the mortar together and assists in preventing the mortar from being pushed through the lath. The hair should be long and free from grease. Hair is packed in paper bags weighing about 8 pounds.

Jute fiber is generally used as a satisfactory substitute for the hair which it has rapidly superseded in favor. The fiber should be cut in 2- to 3-inch lengths. All rough gypsum plasters are mixed with jute fiber as the binding agent.

Gypsum Plasters.—The active cementing agent of gypsum cement is obtained by heating gypsum rock until the water of crystallization which it contains is expelled. The resulting white powder, plaster of paris, when mixed with water into a paste sets and becomes hard in a few minutes. When mixed with a retarder, jute fiber, and otherwise prepared, it forms the gypsum cement so extensively employed for interior plastering. Gypsum or plaster of paris is soluble in water and for that reason cannot be used for outside work.

Plaster of paris is employed extensively also for gaging the lime paste prepared for the white finish plaster coat. It is sold under various trade names and is usually packed in paper bags for shipment.

Plaster Mortars.—Plaster work is classified according to the number of coats of mortar which are applied as one-, two-, or

three-coat work. Plaster is usually applied on wood and metal lath in three coats. The first coat is known as the scratch coat. It is applied directly to the lath. The second coat is known as the brown coat; it is utilized to bring the plaster to a straight and true surface. The third coat is known as the finish or white coat. Plaster is usually applied on hollow tile, gypsum blocks, or brick in two coats: a brown coat and a finish coat.

Scratch-coat mortar consists of a mixture of sand, hair, or fiber, a cementing material, and water. It should be mixed somewhat rich so that it will adhere strongly to the lath. The correct proportions to be employed vary slightly with the nature of the cementing material and will be discussed later.

Brown-coat mortar consists of the same materials as those used in the scratch coat but the mortar is not as rich. The proportion of sand to cementing material is increased so that there will be less tendency for the plaster to shrink and crack.

The white finish coat consists of lime paste mixed with plaster of paris. The plaster of paris is added to quicken the set and increase the hardness of the white coat.

Gypsum cements intended for plastering are mixed with jute fiber in the correct proportions at the mill before shipment. For scratch-coat mortar, gypsum mortar is mixed in the proportions of one part gypsum cement to two parts sand by weight. In this proportion, a 100-pound bag of gypsum cement will require 2 cubic feet of sand for scratch mortar. Sand weighs approximately 100 pounds per cubic foot.

The mortar should be mixed in a watertight box about 1 foot deep, 4 feet wide, and 7 feet long. The gypsum cement and the sand should be mixed dry to a uniform color. Fibered cement should always be used for the scratch coat and the mortar should be mixed to a slightly stiff consistency. If the mortar is too wet and does not contain any fiber, it is difficult to apply it to the lath. This is particularly true when it is laid on metal lath. If the metal lath has a very open mesh, the scratch mortar should be made rich so that it will not be pressed through the lath. One bag of gypsum cement to 1 or 1½ cubic feet of sand will give a satisfactory mix. Water should not be added until the material is needed for plastering, as gypsum cements require only a short interval of time before they begin to set.

Mixing the Brown Mortar.—The brown-coat mortar is mixed in a fashion similar to the scratch mortar excepting that, in order

to avoid shrinkage and cracking of the plaster, the brown mortar contains a greater proportion of sand. With gypsum cement, the usual mixture is one part of cementing material to three parts of sand by weight. When mixed in this proportion each 100-pound bag of gypsum cement requires 3 cubic feet of sand for the brown mortar. The gypsum cement used for the brown coat mortar is the same as for the scratch coat.

Mixing the White-coat Mortar.—When using lump lime to make the white- or finishing-coat mortar, the lime is slaked into lime paste as previously described, it is then thinned down with water, strained through a No. 10 mesh sieve, and placed in a watertight box for 48 hours to settle and thicken. The resulting fine white paste is mixed later with plaster of paris by the plasterer immediately before applying to the walls. It is particularly necessary that the lime of this finishing-coat paste should be thoroughly slaked to avoid popping from the surface later. This requires a slaking period of a week or more. The settling box should be large enough to hold a week's supply of paste.

When hydrated finishing lime is used for forming the white coat, the process is greatly simplified. Hydrated finishing lime replaces the lump lime. It is already slaked when shipped from the factory. The hydrated lime is mixed with sufficient water in a watertight box to make a thin paste and permitted to remain there for 1 or 2 days for complete soaking. The paste is later mixed with plaster of paris and applied to the walls.

White lime paste when mixed with plaster of paris is known as gaged stuff or hard finish. The plaster of paris causes the mixture to set rapidly and is added to the lime paste by the plasterer as needed. The proportions of lime paste and plaster of paris are determined by the plasterer according to his judgment when mixing them. The best proportion is about one part of plaster of paris to three parts of lime paste by volume. The plaster of paris and lime are mixed by the plasterer on his mortar board. Lime paste is delivered to the plasterer by his helper. The plasterer forms a ring of the lime paste on his mortar board and then fills the enclosed space with water. Dry plaster of paris is then sprinkled evenly in the water until the water is absorbed and the materials are mixed together thoroughly with a smoothing trowel. The gaged mortar is then ready to be applied to the walls. The plaster of paris gives a hard finish to the plaster and is needed because the lime paste is somewhat inert.

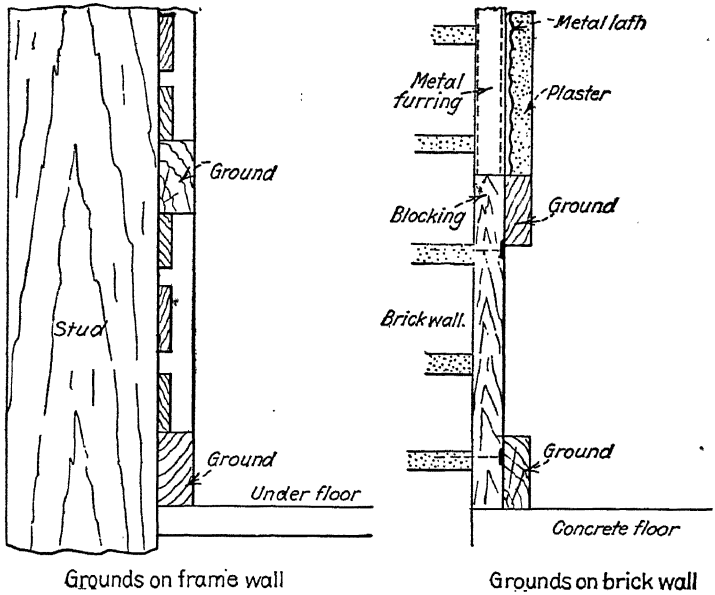


FIG. 222a.—Base grounds.

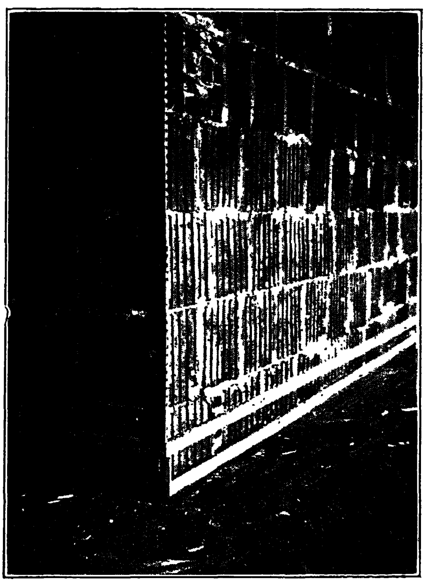


FIG. 222b.—Grounds and corner bead.

Plaster of paris is shipped in cloth sacks containing 100 pounds or in paper bags containing 80 pounds. Lime and plaster of paris are sold by weight. One part of plaster of paris and two parts of lime by weight should be ordered to obtain a proportion of 1–3 by volume.

Application of Scratch Coat.—The scratch coat is the first coat of plaster applied in three-coat work. It is the first coat laid on

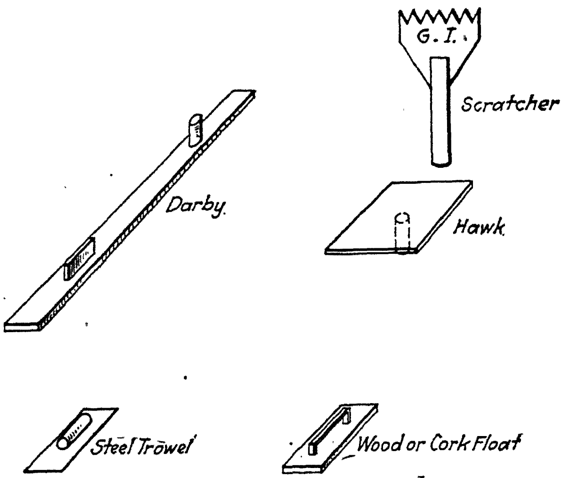


FIG. 223.—Plasterer's tools.

both wood and metal lath, and is intended to serve as a foundation for the subsequent coats. The scratch coat is not thick, usually not over ¼ inch. Preferably, the coat should be put on as thin as possible. It is impossible at this stage of the plastering to tell just how far out the surface of the plaster will be. It barely covers the lath but it is made sufficiently strong to adhere to the lath.

The mortar for the scratch coat is mixed as previously described. It is carried by the plasters' tenderers in hods from the mixing box and is deposited upon small platforms, called "mortar boards," from which the plasterer obtains his mortar. A mortar board is usually made about 4 feet square and should preferably be supported by a stand about 30 inches high.

The tools used by the plasterer in putting on the scratch coat are a steel smoothing trowel, a hawk, and a scratcher, shown in Fig. 223.

In applying the mortar, the plasterer with his steel trowel fills his hawk with several trowelfuls of mortar from the mortar board.

Having loaded the hawk with all it will hold, the plasterer proceeds to lay the mortar on the lath, taking it from the hawk with the trowel and spreading it over the lath. He starts at the bottom of the wall and works upward. Each trowelful is applied with an upward motion and is made to overlap those previously applied, until the whole surface is coated. The mortar is pressed against the lath so as to form a strong key. The thickness of the coat will vary but is usually not thicker than ¼ inch.

Where the mortar is applied over metal lath on brick walls, it should be laid on lightly, so as not to press the mortar into contact with the brick masonry. Where plaster comes into contact with a damp wall, it absorbs dampness and the moisture shows as a wet spot which discolors the surface. If applied with too much pressure, or if the mortar is too lean, the mortar will fall off behind the lath and fill the space solidly between lath and wall to a height of 2 or 3 feet above the floor.

If the scratch coat is to be applied to wood lath, the laths should be thoroughly wet the day before and again sprinkled an hour or so before plastering. This is to prevent swelling and buckling of lath such as would occur if the plaster were applied to dry lath. After the coat has hardened somewhat, the surface is scored with scratches to provide a bond for the following coat. The scratches should cross each other diagonally about 2 inches apart. Horizontal scratches are apt to weaken the key of the mortar when it is laid on wooden lath. Where metal lath is used, the scratches may be made vertically and horizontally without any ill effect. The scratch coat is so called because it is the only coat that is thoroughly scored and scratched in preparation for the subsequent coats.

Application of Brown Coat.—The brown coat is the second coat laid on in three-coat work. It is at least ¼ inch thick. It might be called the straightening coat, as by its application the plaster surface is brought to a straight and smooth plane. The brown coat is so called on account of the color which is caused by the liberal proportion of sand contained in the mortar. When the second coat is in place and the work is ready for the white coat, the walls are said to be "browned." The brown coat is laid on with the aid of screeds to obtain an even surface. In

screeded work, the brown coat is not applied until the scratch coat is hard and strong enough to resist the pressure of applying the brown coat. For this reason, the brown coat should be soft

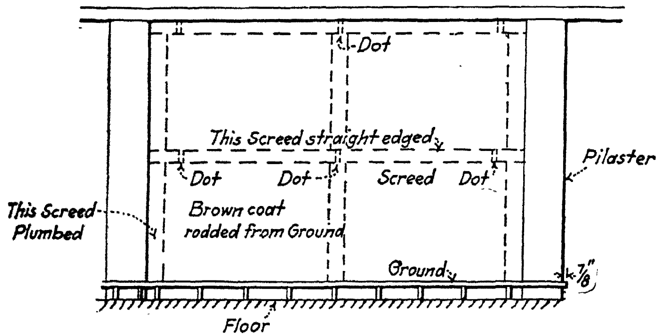


FIG. 224a.—Plaster wall screeds for brown coat.

enough to enter the scorings in the scratch coat and, also, to be laid on without cracking it. The brown coat should be applied preferably before the scratch coat is thoroughly dry.

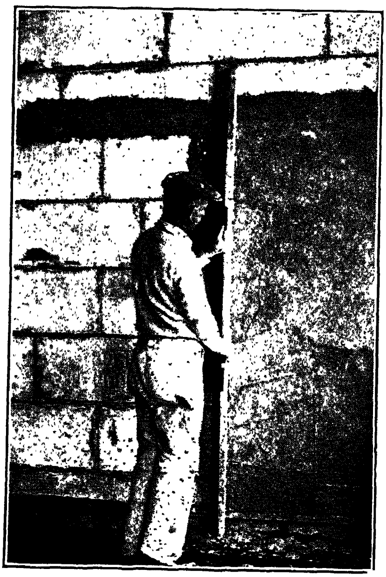


FIG. 224b.—Rodding the brown coat.

Screeds are guide strips of mortar formed as part of the brown coat. In plastering walls, the first screed is formed about 7 feet above the floor extending horizontally. The second horizontal screed is formed on the wall close to the ceiling (see Fig. 224a). Screeds are formed in horizontal bands across the surface of the wall, by building "dots" or guide points consisting of a piece of wood stuck in place with plaster of paris. A screed is a band of mortar about 6 or 8 inches wide. It is applied by the plasterer with a steel trowel while standing on the floor, and is built up as high as the plasterer can reach. The "dots" are plumbed up from

the ground with a straightedge and a level so as to be flush with the surface of the ground. A horizontal screed is then built up across the wall from the dots. This screed is made true by a long straightedge reaching horizontally over at east three dots. Vertical bands of mortar are then formed at corners and intermediate points.

This operation covers the lower 6 or 7 feet of wall with a mortar framework which may be filled in with soft mortar and may be brought to a true plane by means of a straightedge or "rod" as it is called. Intermediate vertical screeds may be formed where they are thought desirable. The panels between the screeds are filled with a steel trowel and, after being rodded as mentioned, the surface of the mortar is smoothed down with a long two-handled float called a "darby" (see Fig. 223). The surface is then further packed and smoothed with a small wooden float. To form a scoring which will provide a bond for the finish coat, the float is sometimes provided with a small steel nail loosely inserted in the wood which can be pushed forward when needed and can be made to scratch the plaster as the float is guided over the surface of the plaster. Great care must be exercised to form the angles at all vertical corners straight and plumb, as any imperfections are easily perceived at such locations. In this connection, it might be mentioned that in such locations as at the edges of pilasters where they project inside the room it is of more importance that the edge of the pilaster should appear parallel to the surface of the wall than that the reveal should measure the exact width shown on the plans.

The vertical screeds in Fig. 224*a* are not essential, as the plaster can be easily rodded from the horizontal screeds. The rodding can also be done from vertical screeds when necessary. The method represented in the figure is known as dotted work. It is the most expensive. Plastering can be more economically done by omitting the dots and forming horizontal screeds of mortar with a straightedge. In cheap cottage work there is no ground to rod from and the plasterer builds horizontal screeds of mortar in the simplest manner possible.

In brick buildings, the plaster of the walls must be returned around the corner of the window opening. This may be done by running a rounded corner in the white coat plaster with a bull-nose mold, or by forming the corner with a metal corner bead. When the corners are made with corner beads, the brown

mortar can be easily rodded around the windows by rodding horizontally and vertically from the corner beads.

In laying on the brown coat, the wooden ground provides an important and accurate base from which the plasterer can work. It should be noted that the outside surface of the ground coincides with the finished surface of the wall. This is the same as saying that it should be flush with the exterior surface of the white coat.

When the plasterer applies the brown coat and straightens it, he works his straightedge or "rod" up and down the surface of the wall with one end bearing against the ground. This action brings the face of the brown coat flush with the ground. In cheap work, this is permitted to be the final position of the brown coat, over which the white coat is applied. In first-class work, during the process of consolidating and smoothing the brown coat with the darby and float, the mortar is pressed and packed back so that it lies approximately 1/8 inch behind the surface of the ground. This provides space for the application of the white coat. It is good practice to cut a bevel in the brown coat plaster just above the top base ground to make sure there is space for the white coat there.

The lower portion of the wall having been browned, as just outlined, a staging is built from which the plasterer can plaster the ceiling. The staging for a ceiling of ordinary height can be best formed of 2-inch planks supported on wooden horses. To be in the most convenient position, the top of the platform should be about 6 feet 4 inches below the ceiling. Where the ceiling height is over 12 feet, it may be necessary to erect a post scaffold. A staging supported on horses is the most economical, as sufficient staging for a small portion of the area only need be provided. The staging is shifted as the plastering progresses. No halt in the plastering need occur; the plasterers can be working on one end of the staging, while the tenders are moving the planks and horses at the other end. The remaining upper portion of the wall is plastered from the same staging; screeds are built as previously described as a guide for the brown coat. Before applying the brown coat over hollow tile or brick, the walls should be dampened, although plasterers frequently omit dampening. Partitions of gypsum blocks are always sprinkled with water from a brush before the brown mortar is applied. The walls are dampened to reduce the suction and loss of moisture from the

mortar. This precaution prevents what are known as "fire checks" or small cracks in the surface of the plaster.

Application of the White Coat.—The finish coat is not applied until the brown coat has become firm. The white coat may be applied when the wall is about half dry. If applied when the wall is entirely dry, the white mortar has a tendency to roll under the edge of the trowel. If the plaster is to be painted, the brown coats should be allowed to dry for ten days before the white coat is laid on. This will give time for all moisture in the brown coats to dry out. The white coat can then be applied and the painting can follow a few days after. If the white coat is put on a day or two following the brown coats, the walls may stay damp for several weeks so that the painting can not be done.

The ordinary white finish coat is laid on about 1/8 inch thick and is smoothed and polished with a steel trowel and a water brush to a satisfactory surface. The white mortar is applied in one coat but in three operations. In the first operation, the paste is spread on thinly using only sufficient material to cover the surface completely, pressing it thoroughly into the brown coat. This is termed "scratching in." In the second operation, the coating is applied with enough material to bring the surface of the wall to a straight and even surface. This part of the process is termed "doubling up." The third time the surface is gone over, all imperfections and cavities are filled and smoothed over. After the second coating, the plaster in all corners is smoothed off to an even surface with a straightedge about 4 feet long having a sharp, beveled edge. This tool is known as a featheredge. In the final troweling, the plaster is brought to a finished surface by continually passing over it with the trowel and a damp brush. Cheap work, which is intended for painting or for covering with paper, is frequently given a skim or slipped coat finish.

In applying the white finish coat, the ceiling is usually covered first, then the top portion of the sidewalls, which may be reached from the same staging, and finally the lower portion of the walls down to the base grounds. When possible the entire wall between floor and ceiling should be covered with the white coat in one operation and the white mortar should be smoothed with the darby where it is applied over the screed in the brown coat. This precaution will prevent slight bumps and depressions from forming over the screed. The operation of smoothing with the darby is known as "flanking."

Plastering a Concrete Ceiling.—Plaster applied to the under side of a concrete floor by employing ordinary plaster and ordinary plastering methods cannot always be relied upon to adhere. Concrete, in drying and completing its set, throws off its surplus water to the surface, carrying with it salts of various kinds that destroy the adherence of plaster. Special plasters which will adhere permanently to a concrete ceiling are sold under trade names and may be obtained from manufacturers of gypsum cement. Bonding plasters are white in color and are mixed with water only. They are applied thinly over a concrete

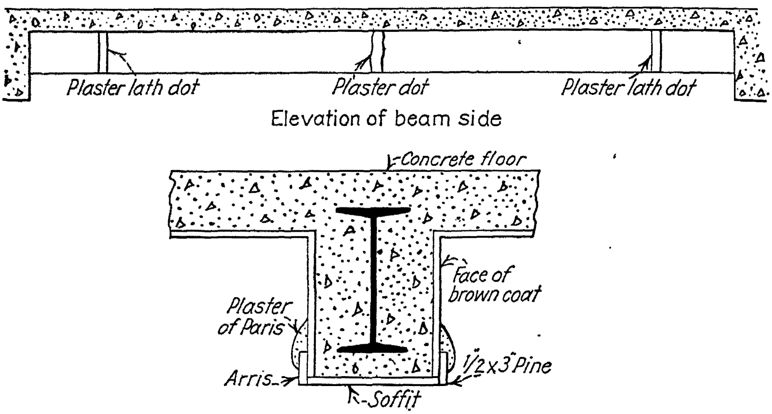


FIG. 225.—Forming arrises.

surface and immediately after, while soft, are covered by a slip-on coat of brown mortar. White finish mortar can be applied directly over the bonding plaster on the following day, if desired.

Arrises.—Steel beams in a fireproof building, as usually constructed, are encased in a fireproofing of concrete. In applying plaster to the soffits and sides of these beams, care must be exercised to make the sides plumb and the arrises sharp and straight. The method employed to do this is represented in Fig. 225.

The sides and soffit of the beam are covered with a coating of bonding plaster. Two or more dots are then formed on each side of the beam to guide the surfacing of the brown coat. If there are to be two dots, they may be made of pieces of plaster lath stuck in place with plaster of paris. To save plaster, the lath should be planed down to a thickness of $\frac{3}{16}$ inch. Care should be taken to make the surface of the dots plumb, using a level

for the purpose. If possible the soffits of all beams should be made the same width by arranging the dots on opposite sides

FIG. 226a.—Applying brown coat over bond.

FIG. 226b.—Applying white coat on soffits.

the same distance apart. If the beams are long, a third middle dot is formed near the center of the span. The third dot can be

most conveniently formed of plaster of paris. To bring it flush with the end dots, a chalk line can be stretched from one end dot to the other and the middle dot can be built up to the line.

The brown mortar is applied to the sides of the beams and made flush with the dots by means of a straightedge. The pieces of plaster lath are then removed.

When the brown coat mortar has hardened, two strips of wood ½ inch thick and 3 inches wide are fastened on the sides of the beam with their lower edges flush with the intended soffit of the beam. The edges and sides of the strips have to be carefully brought into a straight line by the means of a long straightedge. The strips are preferably of white pine and are tacked to the sides of the beams with nails spaced a foot or two apart. They are further secured by plaster of paris applied at intervals to the upper edge.

The strips are placed in position and the white coat mortar is applied to the underside of the beam directly on the bond coat, and formed into a straight flat soffit by a straightedge worked back and forth across the bottoms of the two strips. When the soffit is completed, the strips of wood are removed and the white coat is applied to the sides of the beam.

The method just outlined is employed on first-class work. A saving in labor may be obtained by substituting small vertical screeds in place of the dots and straightening the brown coat with a long straightedge.

ORNAMENTAL PLASTER

Ornamental Plastering.—Ceilings may be ornamented with cornices placed in the angle formed by the intersection of the walls and ceilings; the cornices may be embellished by small moldings and plaster castings arranged along its surface. Ceilings of important rooms, also, may be divided into panels by real or false beams; the panels may be decorated by ornamentation placed along the sides and soffits of the beams and in the corners formed at the ceiling by the sides of the beams.

The sharp corners and curved profiles of a plaster cornice are made almost entirely of white gaged plaster which is molded in place by using special tools. The ornamentations with which the cornice is embellished are cemented in place by a paste of plaster of paris. In short, it may be said that all cornices and coves are

"run on" and that all casts such as corbels, beadings, and egg-and-dart moldings are "stuck up."

When a room is to be plastered and the ceiling is to be ornamental, the cornices and coves should be run first, after which the plaster casts are stuck up. This is followed by the application of the white coat to the ceiling and then to the walls.

FIG. 227.—Running a cornice.

A cornice or plain molding is run on by means of a special molding tool made by fastening a piece of galvanized sheet iron to a framework of wood. The sheet iron is cut out to a reverse profile of the molding, and when pushed along a surface covered with soft white gaged plaster, leaves behind it a number of projecting ridges and incised chases which form the desired profile.

Plaster molding tools are shown in Figs. 229 and 230. The molds illustrated in Fig. 229 are intended for running a plaster cornice along the side of a beam. The plaster is applied over a base of metal lath tied to a framework of flat steel bars. The metal lath is covered with a scratch and brown coat before the white coat is run with the mold. The molds illustrated in Fig. 230 are intended for running a bull-nose corner on a window

opening. All molds are designed so that they can be pushed along a running-rod. An inspection of Figs. 227 and 228 (photographs)

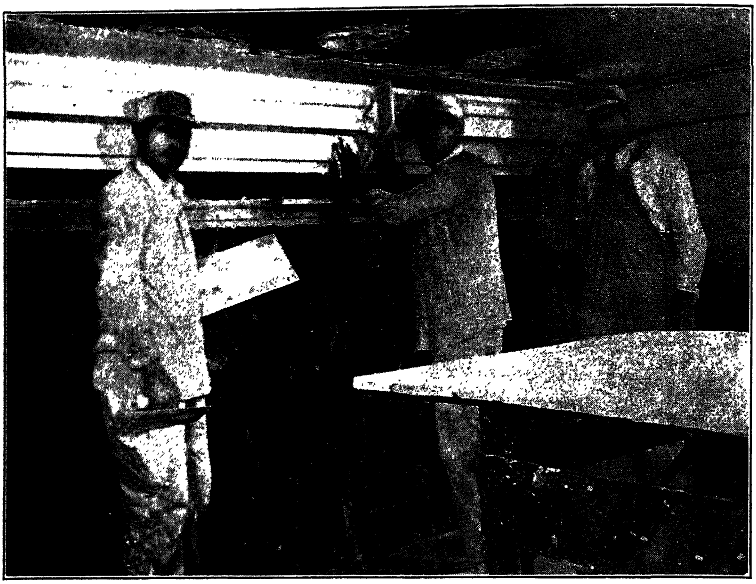


FIG. 228.—Running a cornice.

will do more to make clear the method of running a cornice and the construction of the molding tool used than several pages of

FIG. 229.—Cornice molds.

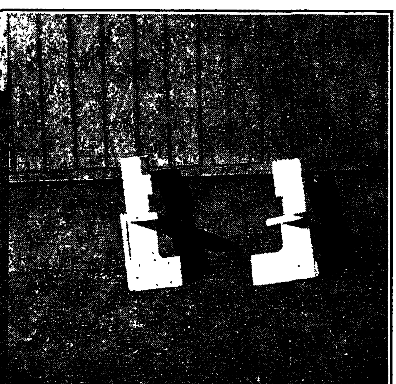


FIG. 230.—Bull-nose molds.

description. In running a cornice, as may be seen in the figure, the mold is pushed along a strip of wood which serves as a guide.

The strip of wood, or "running rod," as it is called, is either nailed in place or stuck on with plaster of paris. At times it is necessary to erect a horizontal piece of 2-by-4 scantling just below the cornice to act as a running rod. The mold can seldom be run to the mitered corners at the ends of the cornice, so the corner miters have to be formed by hand. To guide the upper edge of the mold, a small strip of the ceiling is covered with white plaster smoothed with the trowel. On this smooth white surface, a line is marked along which the top edge of the mold is guided.

Ornamental designs such as egg-and-dart moldings, dentils, and similar figures must be cast separately. Usually they are purchased from companies which make a specialty of manufacturing ornamental plasterwork. The casts are shipped to the building and stuck in place with plaster of paris which has been mixed with water to the consistency of a thin paste. Ordinary plaster of paris has a gray-white color. Ornamental casts and moldings are made in short lengths and, if the color of the plaster used to stick up the casts does not match that of the casts, the joints will show dark and the edges of casts will be discolored. Pure-white, superfine molding plaster with no lime should be used for this purpose if a high-class result is desired or the joints can be pointed with gaged lime. If the plaster is to be painted these precautions are not necessary. In all cases, the casts should be washed in clean water to kill the suction and remove any dust or dirt before they are stuck up in place.

MAKING ORNAMENTAL PLASTER CASTS

Glue Mold for Casts.—A mold has to be prepared when a number of plaster castings are to be made. It is intended in these paragraphs to explain the work incidental to making ornamental

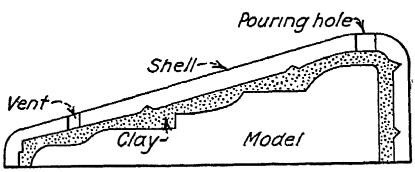


FIG. 231.—Making the mold shell.

plaster casts. The process consists of three main operations: first, making the model; second, making the mold; third, making

the casts. To simplify the description of the process for the reader, the successive steps are outlined in a tabulation.

The making of a model will vary with the shape required and it may be necessary to form it in a slightly different way from that outlined. The making of the mold is represented in Fig. 231. The making of the plaster cast is represented in Fig. 232. The illustrations and text describe the operations involved in making a cast that is to be part of an ornamental plaster wall bracket concealing inverted lighting fixtures.

Making the Model

1. The model is made by running a molding of white plaster on the bench and subsequently cutting off sections of it in a miter box.
2. Extra parts are formed and added by handwork.
3. The completed model is covered with shellac.

Making the Mold

1. The model is covered with a layer of potter's clay about ¾ inch thick. The clay layer is then coated with stearine to prevent sticking

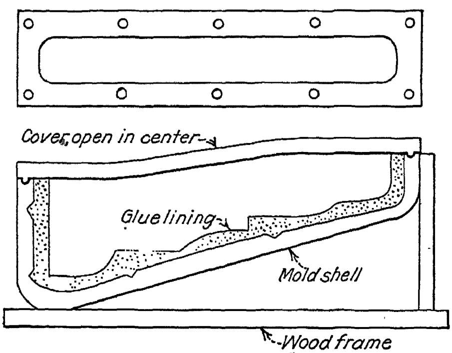


Fig. 232.—Glue mold for plaster casts.

2. A shell is made by covering the clay with a layer of plaster of paris 1½ inches thick, as shown in Figs. 231 and 232. It may be reinforced with burlap and pieces of iron rods.
3. The shell is made in two parts: the shell proper and a cover. The cover is shaped to conform to the profile desired in the back of the casting.

4. Button-shaped holes are made in the edge of the mold shell so as to form projections in the cover. This is done so that shell and cover will always occupy the same position when brought together.

5. Two holes are made in the shell. One is to serve as a pouring hole, the other as a vent.

6. The clay is then removed.

7. Melted glue is then poured into the space formerly occupied by the clay.

8. The original model is removed about 24 hours later, leaving a completed mold with a thick pliable coating of glue that has a consistency of soft rubber.

Making a Cast

1. The mold is then turned over in the position shown in Fig. 234.

2. The face of the glue mold is then rubbed with powdered alum to prevent the glue from being affected by the heat of the

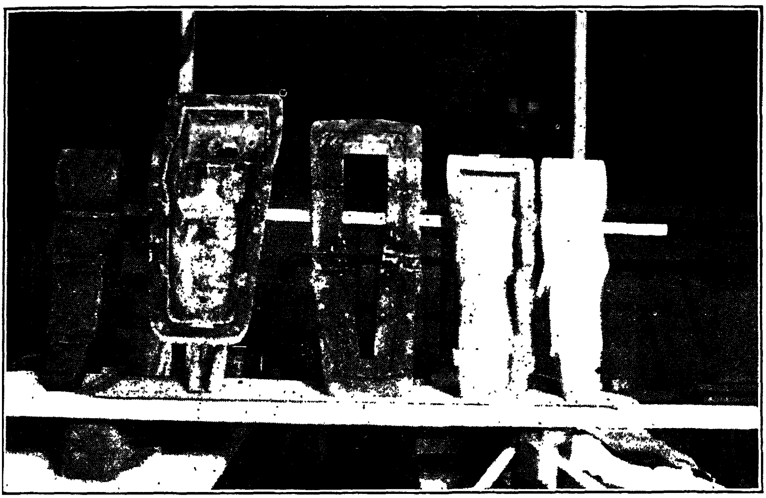


Fig. 233.—Model, shell, cover, glue lining and cast.

cast. The surface of the glue and of the shell cover is then dusted with powdered soapstone to prevent sticking.

3. The casting is made by filling the mold with gaged plaster. Large plaster castings are never cast solid but are made as a hollow shell with a thickness of 1 to 2 inches. The cover of the

mold shell is open so that the interior of the casting is accessible.

The following materials are required for a medium-sized job of ornamental plaster-casting work:

Powdered alum...	5 pounds	Stearine.....	25 pounds
White gelatine glue	100 pounds	Modeling clay......	200 pounds
Soapstone.........	25 pounds	Scotch burlap ¼ inch mesh.....	200 square yards

A bench for running moldings for models with a molding tool is illustrated in Fig. 235. A molding tool is shown in position to run

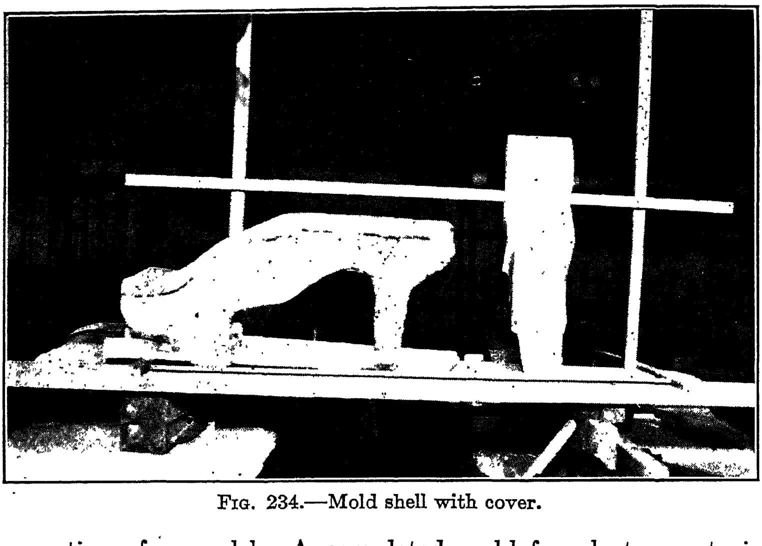


FIG. 234.—Mold shell with cover.

a portion of a model. A completed mold for plaster casts is shown in Figs. 233 and 234. In Fig. 233, as viewed by the reader, the original model is shown at the extreme left. Next to it is the shell. The third object is the cover. Next in line is the glue lining which has been removed from the shell. At the extreme right is a finished casting.

Stucco.—Stucco is the designation commonly applied to plaster coatings on the exterior walls of buildings. A stucco mortar is composed of portland cement, sand, and sufficient water to make a plastic mass. Other materials are often added. To increase the plasticity and spreading qualities of the mortar, a

small proportion of hydrated lime is frequently mixed with it. As a cement plaster is somewhat porous, it is advisable to add some waterproofing material to the mixture. Hydrated lime by increasing the plasticity decreases the porosity of the stucco, but there are manufactured products on the market which are more certain in their action.

Stucco may be applied to brick, tile, or concrete walls directly on those materials or it may be applied on a supporting base of wooden or metal lath. The most dependable base to which a

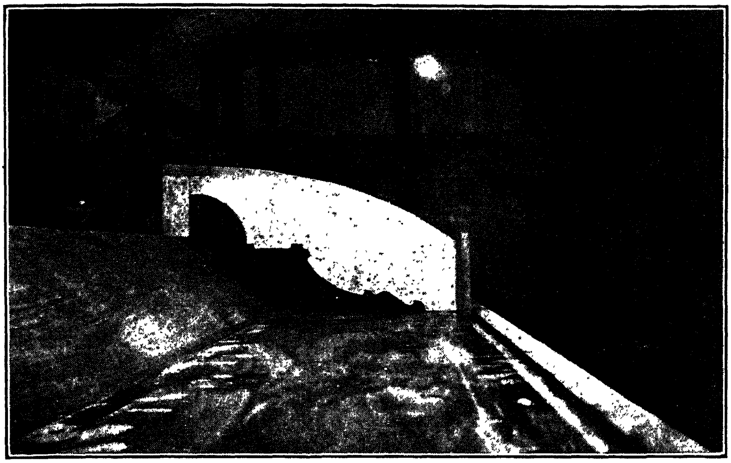


FIG. 235.—Bench for running molding.

portland-cement stucco can be applied is metal lath. When a cement plaster is applied to the surface of a concrete wall, there is always some possibility of the stucco separating from the wall unless great care is exercised in providing a bond between the two. When a cement plaster is spread over the surface of a brick or tile wall, an efflorescence is likely to be formed on the surface of the stucco and spoil its appearance. There is also a possibility of the plaster loosening from the wall. When cement stucco is applied on wooden lath, should the lath become damp, it will swell and crack the plaster, bringing about the destruction of the stucco eventually. These conditions are mainly brought about by moisture penetrating the cement plaster, but are not likely to occur in dry locations.

Mixing the Mortar.—A cement mortar should be mixed in the proportion of one part of cement to three parts of sand. Richer

mixtures than this are likely to crack due to the contraction of the cement while setting; the amount of contraction is in direct proportion to the amount of cement. A leaner mixture than 1 to 4 should not be used. A cement plastering mortar is usually specified as containing lime to the extent of not over 10 per cent of the quantity of cement by weight. This is equivalent to one-fourth the quantity of cement by volume. The lime is most conveniently added in the form of hydrated lime. The powdered lime should be mixed dry with the cement. The lime replaces an equal quantity of cement. The combined bulk of lime and cement is mixed with three times as great a quantity of sand. The mixture of lime and cement should be mixed dry with the sand until the mass is of an even color; it should then be spread out and formed into the shape of a basin into which the water is poured. The whole is mixed until the cement color is uniformly distributed throughout the mass. If mortar is mixed without lime, it will lack cohesion and cannot be applied easily over metal lath, as the sand and cement mortar will run through the lath as fast as it can be laid on. A good specification is that all mortar for stucco shall contain lime in the proportion of 10 per cent of the cement by weight and that the mortar for the first or scratch coat shall contain hair or fiber in the proportion of 1 pound of hair or fiber to each bag of cement.

Application of the Stucco.—The application of a cement stucco follows in a general way the methods outlined previously for plastering interior walls. The stucco may be put on in either two or three coats. When laid on metal lath three coats are usually necessary, if an even surface is desired. The first or scratch coat is applied thinly over the lath with a steel trowel and scored with a toothed scratcher to provide a bond for the second coat. The second coat is applied as soon as the scratch coat has set hard enough to withstand the pressure incurred in laying on the second coat. This usually may be applied on the day following the application of the scratch coat. If a straight and even surface is desired, mortar screeds should be built over the surface of the wall and the panels thus formed should be filled and smoothed with a wooden float. The surface of the second coat should be lightly scored so as to hold the finish coat. The finish coat will adhere best to the previous coats if it is applied after the latter have set up hard and dry. This will usually require an interval of 4 or 5 days.

The appearance of a stucco plaster may be made to vary in many different ways. Several variations may be obtained by manipulating the trowel and leaving marks of the trowel in the surface. Other variations in texture may be obtained by using various materials in the finishing mortar and by applying the finishing mortar in different ways. The finishes most commonly seen are the floated finish, spatter dash, torn texture, and stippled finish.

Floated.—A floated finish is that which is left by the manipulation of the cork or wooden float used in smoothing and packing the second coat. The float is moved over the surface of the plaster with a rotary motion leaving a flat even surface which is slightly rough in texture and not as smooth as that which would be left by the steel smoothing trowel.

Spatter Dash.—A spatter dash finish is made by covering the wall with a coating of 1 to 3 mortar thrown forcibly against it. Care should be taken to make the coating uniform. The mortar may be cast from a trowel, a stiff bristle brush or broom, or a bundle of twigs. If the spatter dash is to be applied to the surface of a concrete foundation wall, a preparatory coat of cement should be spread over the wall with a smoothing trowel and the spatter dash is then applied over this coat. Previous to plastering, the wall should be brushed with a broom and thoroughly moistened so that water from the plaster is not absorbed into the wall.

Stippled Finish.—A stippled finish is made by laying on a finish coat of mortar, troweling it smooth, and patting the surface with a brush of coarse bristles or broom straw. The ends of the bristles should be applied to the surface. The stippling may be done uniformly or not, as may be desired.

Colored Stucco.—Stucco may be colored by the addition of various pigments to the mortar. The colors most commonly employed are yellow, red, and black. Colored pigments act as dilutents and have a weakening effect on the strength of the mortar. They should not be used in greater proportion than 10 per cent of the quantity of cement by weight. Cement plaster which has been mixed with too great a proportion of pigment is inert and washes away readily when exposed to a rain.

The following table gives the weight of various pigments that should be added to each bag of cement to obtain various shades of colors.

Table of Colors

Color	Coloring material	Pounds of color required per bag of cement	
		Light shade	Medium shade
Grays, blue-black, and black	Germantown lampblack	½	1
	Carbon black	½	1
	Black oxide of manganese	1	2
Blue shade	Ultramarine blue	5	10
Brownish red to dull brick red	Red oxide of iron	5	10
Bright red to vermilion	Mineral turkey red	5	10
Red sandstone to purplish red	Indian red	5	10
Brown to reddish brown	Metallic brown (oxide)	5	10
Buff, colonial tint, and yellow	Yellow ocher	5	10
	Yellow oxide		
Green shade	Chromium oxide	5	10
	Greenish blue ultramarine	6	

Cement mixed with coloring matter ready for use can be purchased. As used in house construction, the top coat only is made of colored mortar, the underlying coats of ordinary cement mortar. Stucco exteriors with colors graduating from one shade to another may be obtained by painting ordinary cement stucco with waterproof cement paints.

CHAPTER X

SCAFFOLDS AND MATERIAL TOWERS

A scaffold is a wooden platform built temporarily for the support of workmen and materials. While any design which is substantial and suited to the purpose for which it is intended may be employed, there are several forms of scaffolds which have been developed and which have been uniformly adopted as standard types of construction.

The most familiar form of scaffold in general use is the *post scaffold.* This scaffold, as the name implies, consists of vertical posts or uprights supporting the weight of the platform. It is in general use by all branches of the building trade, particularly by bricklayers, stone masons, carpenters, and pipe fitters.

A *post scaffold* is used on buildings up to about five stories high, but at that height the system becomes cumbersome. The building laws of most cities, as well as the economics of design, usually call for buildings of that height to have a framework of steel; some kind of suspended scaffold is then most convenient to use.

A *suspended scaffold* is most useful on buildings over three stories in height. Where the suspended scaffold is employed, the steel building frame is usually completed. It is then possible to hang the scaffold to the topmost part of the frame. By suitable arrangements of sheaves, the platform can be raised or lowered and the entire surface of the building walls is made accessible.

A *needle-beam* scaffold is a simple arrangement of two beams supporting a plank platform, the structure being hung by ropes from supports overhead. The needle-beam scaffold is most frequently used by structural iron workers.

An *outrigger* scaffold is frequently used in building work. It consists of a platform supported by horizontal timbers which are projected outward through the window openings and secured to the floor beams at one end so as to support the working platform outside the building.

A *horse scaffold* is a simple arrangement of wooden horses and platform planks. It is in common use with bricklayers and by piling one upon the other they are frequently carried four or five tiers in height.

There are various other types of scaffolds which are occasionally employed which, while they are useful in special cases, their field of usefulness is not general enough to justify any extended discussion in this book.

Two-post Scaffold.—The two-post scaffold (Figs. 236 and 237) is in common use in all classes of construction work. It is possible to build it so that it will have great strength and stability by using heavy structural members and adequate systems of bracing. It is useful in building work, where it is neither possible nor desirable to support any of the platform load on the walls of the building. It is the type of scaffold employed by stone masons and frequently by bricklayers. Plasterers and decorators employ it for reaching the high portions of the interiors of buildings. It is used also by pipe fitters and by sheet metal workers for erecting corrugated steel and for similar purposes.

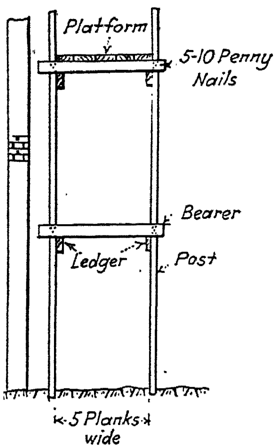


FIG. 236.—Two-post scaffold.

A certain amount of judgment may be exercised in proportioning the different parts of the two-post scaffold. Naturally enough, a scaffold intended for the use of stone masons or of bricklayers, where the weight of materials piled on the platform may be considerable at times, should be of heavier construction than a scaffold intended for the use of painters, where the load outside the weight of the men will consist of nothing heavier than a can or two of paint.

The sizes and proportions given in the sketches in this section are those commonly employed for ordinary construction work and may be increased or made smaller, if thought desirable, to suit conditions of heavier or lighter loading.

Uprights.—The uprights or posts, as shown in Figs. 236 and 237 are commonly made of 3-by-4 timbers. Spruce is the best material but yellow pine is also good. In light work, they frequently

are 2-by-4 studding although this is rather light construction for a scaffold of any height. For heavy work 4-by-4 or heavier posts may be used.

The posts may be spaced to suit the load that comes on the platform. In practice, however, they are spaced either 7 or 10 feet on centers lengthwise of the scaffold. In the vicinity of New York, uprights for bricklayers scaffolds are commonly spaced 10 feet. A 10-foot spacing with platform planks 12 feet long is a preferable arrangement. A closer spacing is needlessly expensive, as too much lumber is required. This spacing permits the use of shorter and lighter planks. The long planks are

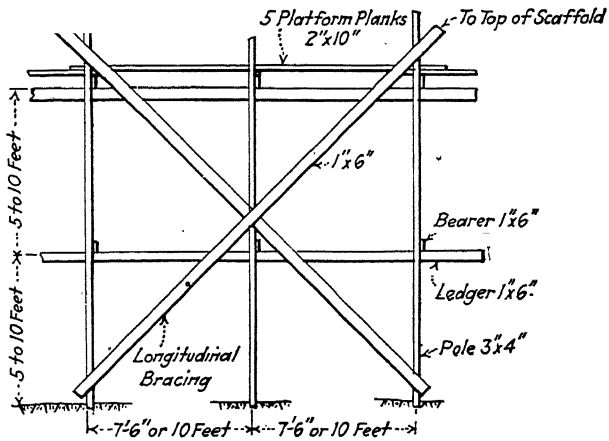


FIG. 237.—Two-post scaffold. Side view.

heavy to handle. The spacing of uprights depends mainly on the length of the platform planks. If the planks are 12 feet long, the posts should be spaced 10 feet on centers and the planks will overhang the supports about a foot at each end. Filler pieces are not required over any of the supports when a plank rests only on two supports.

If the planks are 16 feet long, the posts should be spaced 7 feet on centers and the planks will overhang the supports a foot at each end. When a plank 16 feet long is placed in a platform with posts spaced 10 feet, it overhangs the supports about 3 feet at each end and there is a needless waste of lumber. A filler piece is necessary over the middle cross-bearer or ledger, when a plank rests on three supports.

The width of the scaffold and, consequently, the distance apart of the two lines of posts (Fig. 236) will depend upon circumstances, but for most purposes the two lines of uprights should be spaced to admit five 9- or 10-inch planks between them. When the scaffold is built along a wall, the inside row of uprights should be placed 4 inches or more away from it. In any case, they should be placed far enough out to clear all projections and to provide sufficient clearance for access to all parts of the wall.

The lumber for the uprights should be ordered in 16-foot lengths. Where the scaffold is to be built for bricklayers' use and must extend several stories in height, it will be necessary to form the uprights by splicing several lengths together. In making a splice, the ends of two sticks should be sawed off square so as to form a perfect butt joint with full and true bearing. The joint should then be covered by two pieces of board at least 4 feet long. The boards should be securely nailed to adjacent sides of the upright, each board being fastened with five tenpenny nails above the joint and with five nails below it.

Ledgers.—The ledgers or horizontal stringers in the two-post scaffold serve a three-fold purpose. First, and most important perhaps, they stiffen the uprights against buckling. They also help to support the bearers, and in addition form an essential part of the longitudinal bracing.

The unsupported or unbraced length of a wooden post to avoid any tendency to buckle should be limited to about forty times the dimensions of the least side. This consideration would limit the vertical spacing of ledgers and bearers, when 3-by-4 posts are used, to about 10 feet. As a practical matter, however, the bearers and ledgers should be spaced to suit the vertical distance that is desired between platforms. This distance will depend upon how high a man can reach above the platform to do his work. In bricklaying, it is necessary to keep the spacing down to 4 feet 6 inches; for other trades, the platform supports should be placed not less than 6 feet apart so that there will be room for men to stand upright when the platform planks above them are in place.

The standard practice is to use 1- by 6-inch rough boards for the ledgers. When thought desirable, they may be formed of heavier or lighter material, such as 1¼ by 8 inches or 1 by 4 inches. They should be procured in long lengths so as to extend over two bays between uprights. Every ledger should be nailed

securely to the posts with five ten-penny nails. The best position for a ledger is against the inside surface of the posts leaving the outside face of the posts clear for attaching the diagonal bracing.

Bearers.—The bearers or crosspieces consist of boards or planks set on edge (see Fig. 236). They act chiefly as a support for the platform planks. They also, like the ledgers, serve to stiffen the posts against buckling and form a part of the transverse bracing. Like the ledgers, also, they are spaced to suit the distance desired between platforms.

The bearers should be cut long enough to project at least 2 inches beyond the outside of the posts and should rest directly upon the ledgers. When the scaffold is built along a wall, the bearers should extend beyond the inside posts to within 1 or 2 inches of the wall. When employed for bricklaying, the bearer may be extended out beyond the upright toward the wall far enough to support a plank between the upright and the wall. This construction is advantageous where the uprights must be kept away from the wall to avoid projections. It leaves a vacant space in the platform between the inside uprights which may be closed by a board. The standard material for the bearers is 1-by-6 or 1¼-by-8 rough boards; they should be nailed to the posts with five ten-penny nails. In heavy work, the bearers are made of heavier material, 2-inch planks being frequently used.

Platform.—A scaffold platform is usually built of 2-inch rough spruce planks. With wide spacing of posts and bearers and heavy loads, planks of stronger cross-section may be required. Much depends upon the load which will have to be supported by them. Thick planks are heavy to handle and a platform made of them is not easily moved. Planks of any width may be used, but it is preferable to use 2 by 10's or 2 by 9's as the entire weight of the men on the platform may be thrown on one plank and the wider that plank is, the more weight it will sustain. The same thickness of plank is ordinarily employed with posts 10 feet apart as with posts 7 feet apart. With the spacing at 10 feet, planks 12 feet long are suitable. With the spacing at 7 feet, planks 16 feet long may be used. The planks in this case will span two bays.

If we should investigate the strength of a 2 by 10 by computations, we should find that it will just support safely the weight of two 175-pound men standing at the center of the plank when the supports are placed 10 feet apart. This loading creates a fiber

stress of 1500 pounds per square inch, which is above the stress permitted by some municipal building laws but is still within conservative limits for temporary structures. The addition of the weight of an extra man at the center causes a fiber stress above the limits of safety. As a matter of daily experience, however, a sound spruce plank 2 by 10 of full thickness is capable of supporting two 175-pound men on a span of 14 feet. This, it may be said, is above the safe limit for scaffold work.

A scaffold platform should be five planks wide. The planks should be laid tightly together but need not be secured in any way. Care should be exercised not to allow the end of any plank to extend far enough beyond a support so that it forms a tilting arrangement and constitutes a menace to the safety of the men. The platform planks should be placed as shown in Fig. 237, where the ends of one section of planks rest on the planks of adjacent sections. This arrangement is liked by bricklayers as it results in a level platform. It works out well with 10-foot spacing of uprights and with planks 12 or 13 feet long. With uprights spaced 7 feet and planks 16 feet long spanning two bays, an extra 2-inch strip must be placed over the middle cross-piece or bearer. When thought desirable, the planks may be laid on the bearers shingle fashion This results in a sloping surface to the platform which becomes noticeable to anyone

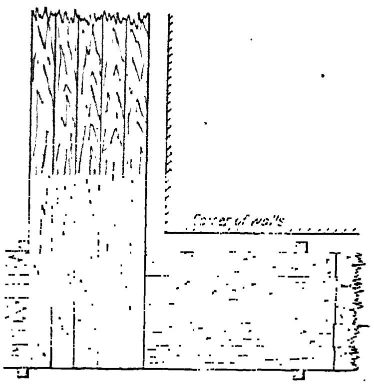


FIG. 238.—Corner of scaffold.

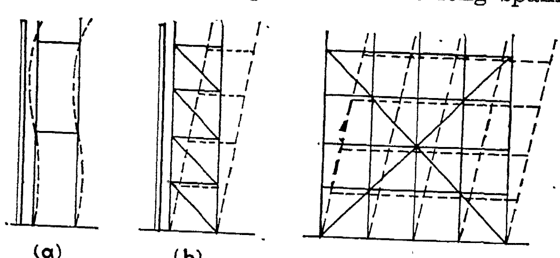


FIG. 239.—Possible ways of scaffold collapse.

standing constantly on it. Another advantage of laying the planks as in Fig. 237 is experienced when moving the platform planks from one level to another, as they can be taken from any place along the length of the platform. If the planks have been laid shingle fashion, this is not so easily done.

A corner of a scaffold should b constructed as shown in Fig. 238. The scaffolds on two opposite sides of the building are extended as far as the line of outside posts on the other two sides. The platforms on these two sides support the ends of the platform planks on the other two sides of the building.

Bracing.—The scaffold should be made secure from overturning bodily by both transverse bracing, as shown in Fig. 239, and by longitudinal bracing as in Fig. 241.

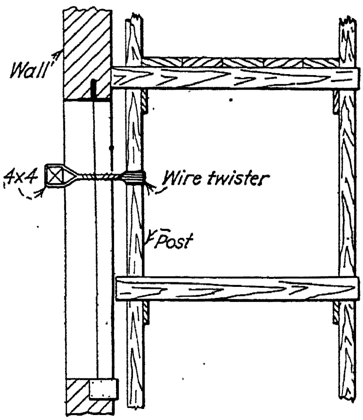


Fig. 240.—A scaffold tie.

The transverse bracing (Fig. 239) should be run in one direction so as not to interfere anymore than necessary with the passage of men along the platform. Ordinary X bracing might be employed but it would be very much in the way. The transverse bracing may be placed on each pair of posts between each set of ledgers. They may be made of 1- by 6-inch boards and secured by four or five ten-penny nails. Transverse bracing is not needed where the scaffold can be tied into the wall. It can usually be omitted on building work, as the scaffold can be easily tied into the building as shown in Fig. 240. The scaffold is tied through the window openings. A piece of 4 by 4 or similar material is placed across the opening on the inside surface of the wall and connected to a scaffold post by several turns of annealed wire. A piece of board can be nailed to the nearest bearer so as to bear against the wall. The turns of wire can then be twisted and the scaffold will be tied rigidly to the wall. Where there are no window openings, the scaffold can be tied in as shown in Fig. 245, or transverse bracing can be installed. It is also possible to brace the scaffold with braces extending to stakes driven in the ground.

The longitudinal bracing should consist of a system of diagonal braces made of 1- by 6-inch boards nailed to the outside surfaces

of the posts. In scaffolds used for work on walls, the braces are nailed on the outside posts only, those on the inside posts are usually omitted as they interfere with work on the wall. They may be installed, if desired, below the working platform as the work proceeds upward. Where a two-post scaffold is erected for

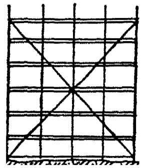


FIG. 241.—Longitudinal bracing of scaffold.

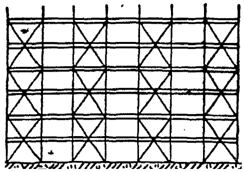


FIG. 242.—Longitudinal bracing of scaffold

pipework or a similar purpose, the longitudinal bracing is usually put on both lines of posts.

Various systems of longitudinal bracing are in use. Typical examples are shown in Figs. 241 to 244. They should be designed to prevent failure, as illustrated in Fig. 239. The longitudinal bracing may extend across the front of the scaffold in a large X, as in Fig. 241, or consist of a series of alternately braced panels,

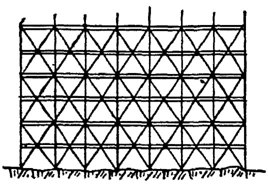


FIG. 243.—Longitudinal bracing of scaffold.

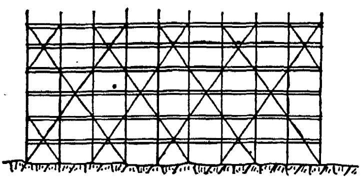


FIG. 244.—Longitudinal bracing of scaffold.

(Fig. 242) or a continuous system of diagonal bracing, as in Fig. 243. A combination of all these systems which combines effectiveness and simplicity is shown in Fig. 244. The system of bracing in Fig. 244 is recommended for general use.

A scaffold braced as shown in Fig. 243 is overbraced. This is a common fault in scaffold building. Many scaffolds are seen that are crowded with bracing. If the length of a scaffold is greater than its height, it need not be heavily braced. Where the height of a scaffold is greater than its length, the longitudinal bracing becomes important.

Scaffold bracing boards should be nailed to each post with four ten-penny nails. Every brace should run from post to post with no splices between the posts.

Code for Scaffolds, New York State.—An excerpt from the New York State Industrial Code is given here to illustrate the requirements in that state.

The following schedules of design and dimensions shall be used for all scaffolds more than 14 feet in height. Materials of different sectional dimensions may be used, but they shall be of equal strength to that given in these schedules. Spacings may be increased if the cross-section of the material and the cross-bracing to be used are increased sufficiently to give strength and rigidity equal to that required by the schedules.

SCHEDULES OF SCAFFOLDS MORE THAN 14 FEET IN HEIGHT

	Plasterers	General	Bricklayers	Stone masons
Posts, end	3″ by 4″	3″ by 4″	by 4″	4″ by 6″
Posts, middle	3″ by 4″	3″ by 4″		4″ by 4″
Runners	1¼″ by 4½″	1¼″ by 4½′	1¼″ by 9″	1¼″ by 9″
Bearers, top		1¼″ by 9″		
Bearers	2″ by 9″	1¼″ by 4½′	2″ by 9″	2″ by 9″
Splice pieces	1¼″ by 4″	1¼″ by 4″	1¼″ by 4″	1¼″ by 4″ 1¼″ by 6″
Braces	1¼″ by 4½″	1¼″ by 4″	1¼″ by 9″	1¼″ by 9″
Spacing posts, longitudinal	6′	6′	10′	6′
Spacing posts, transverse	12′	12′	10′	10′
Spacing sections, vertical	6′	6′ 6″	9′	9′
Distance, wall to posts	22″	22″	31″	31″
Planking	1¼″ by 9″	1¼″ by 9″	by 9″	2″ by 9″
Railing			1¼″ by 4½″	1¼″ by 4½″
Toeboard			by 9″	2″ by 9″

One-post Scaffold.—The one-post scaffold, shown in Figs. 245 and 246, is an adaptation of the two-post scaffold previously described. Its use is almost entirely restricted to the bricklaying trade. As the platform supports on one side are inserted into the brick wall, there are several objections that can be raised against its use, where a fine appearing surface of face brick is desired. Many of the larger construction companies are favoring the use of the two-post scaffold in its place. The one-post scaffold, however, is somewhat cheaper and simpler and will undoubtedly be always used by the majority of bricklaying contractors.

The platform in the one-post scaffold is supported by putlogs placed crosswise under the planks and resting on the ledger,

boards. The latter are nailed to the inside face of the uprights in the same way as in the two-post scaffold.

The chief structural difference between the two types of post scaffolds is that the weight of the platform and load upon it is borne by the bearers in the two-post scaffold, the bearers being nailed directly to the uprights. In the one-post scaffold, the platform load is borne directly by the putlogs and in turn by the ledgers, the latter being nailed to the posts.

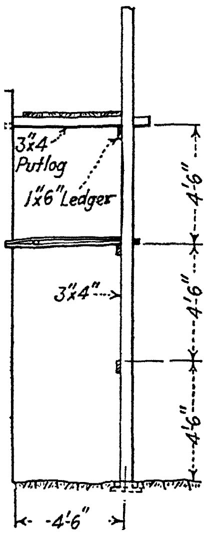


Fig. 245.—Single-post scaffold.

Another difference lies in the transverse bracing. The longitudinal bracing parallel to the wall can be the same in both types, but the bracing perpendicular to the wall is necessarily different, due to the absence of the inner row of poles in the one-post type. In the one-post scaffold the transverse bracing consists almost entirely of ties into the building.

Uprights.—The uprights should be either 3 by 4 or 4 by 4 inches in cross-section and of straight-grained material free from bad knots. They should be spaced 7 or 10 feet apart parallel to the wall.

The distance of upright from the wall may vary with the width of platform desired and the strength of the putlogs. With the usual platform arrangement, the uprights may be placed 4 feet 6 inches from the wall, as shown in Fig. 245.

The bottoms of the uprights are usually placed on a piece of plank laid flat on the ground. A better construction is to bed the block in the bottom of a shallow hole dug in the ground. The foot of each upright is then in a better position to resist any force pushing sidewise on it, whether this force is occasioned by a wheelbarrow or truck or by the reaction from the bracing. The same care in splicing the uprights should be observed as in building the two-pole scaffold.

Ledgers.—The ledger boards are a very important part of the one-post scaffold. They support directly one-half of the platform load and in addition they prevent buckling of the uprights and form the main part of the longitudinal bracing. It is essential that the ledgers be of selected material solidly nailed to the

posts. The standard size of ledger is a 1- by 6-inch rough board 16 feet long. They should be nailed to each upright with five ten-penny nails, and spaced about 4 feet 6 inches apart. The ledgers may be made of heavier material if thought desirable.

Putlogs.—The putlogs are the direct supports of the platform planks. They are horizontal pieces of 3 by 4 or 4 by 4 inches about 6 feet long laid perpendicular to the wall. One end of each putlog rests upon the ledger and the other end rests upon

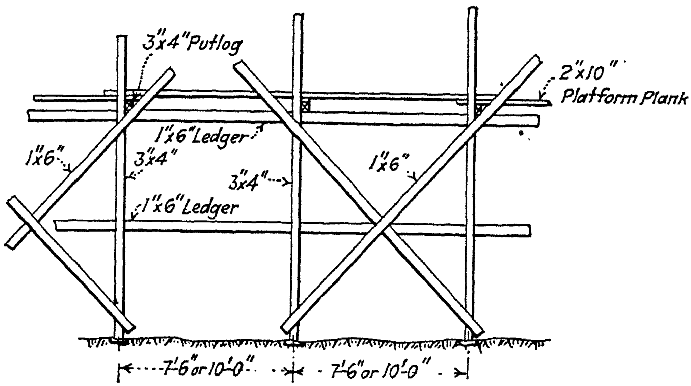


FIG. 246.—Single-post scaffold.

the wall. The putlogs are not fastened in any way to the ledgers, but are simply laid upon them against the side of each upright (see Fig. 246). This will space the putlogs about 7 feet apart and bring three of them under each plank.

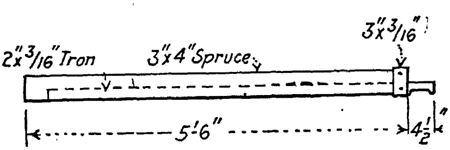


FIG. 247.—Special putlog for brick work.

A putlog formed from a plain piece of 3 by 4 is shown in Fig. 245. One end is notched to rest in the hole provided in the masonry, a brick having been omitted for this purpose. Figure 247 shows a special putlog which is in very general use. It is equipped with suitable irons which allow one end to be inserted in the vertical joints of the brickwork. This is a very

desirable feature, as it is not necessary to omit any bricks to provide a support for them and a good appearance to the exterior of the wall is assured.

Platform.—The scaffold platform should be about 4 feet wide which will require about five 10-inch planks. The planks should be sound and free from all large or loose knots. They should be laid tightly together but a space of 4 to 8 inches should be left between the wall and the inside plank. The space should be large enough to provide access to the face of the wall but not large enough to be a cause of accident to the men.

The planks are not secured against displacement by nails in any way. If the planks are placed as in Fig. 246, the weight of the planks together with materials on the platform will be sufficient to hold them in place. The bricklayers lay the brick to as great a height as they can reach from the position of the platform. It is then necessary to work from a platform laid on the ledger next above them. The platform planks on which they have been working can then be moved to a new position.

A standard spruce scaffold plank, in the vicinity of New York, measures 2 by 9 inches by 13 feet long. Nine-inch spruce planks are carried as a stock size by lumber yards in the region extending from New York to Maine. They are not a stock size elsewhere in the country. In other sections a 2-by-10 spruce scaffold plank is regarded as standard.

Bracing.—The general methods of longitudinal bracing described for the two-post scaffold can be used in the one-post type. The system of transverse or cross-bracing, however, is entirely different. The braces should be nailed to the posts or to the ledgers near the posts at one end and to the window frames or other parts of the building at the other end. They should be put on in such a manner that no movement of the scaffold in any direction is permitted to start. The braces should best be put on in pairs, bracing in two directions.

The braces when nailed to parts of the building may consist simply of pieces of 1-by-6 boards which may be secured to the window frames or to the floor beams. Where no openings exist, the type of brace shown in Fig. 245 may be used. This is known as a "spring stay brace." It is formed of two boards which have been inserted into a hole made for the putlogs at one end and nailed to the ledgers at the other. The boards are inserted into the putlog hole, a brick is placed between them and forced in near

the wall; both boards are then sprung together and nailed to the ledger.

Carpenters' Scaffold.—Post scaffolds for carpenter work are built in a manner similar to those employed for other work but modified in construction by the fact that the platform planks may rest on supports nailed to the frame sides of the building. Figure 248 shows a scaffold used on carpenter work.

A carpenter scaffold is usually of light construction. The uprights, of which there is usually only one row, are spaced 10 to 12 feet apart. With 12-feet spacing, there should be careful inspection of the planking and nothing smaller than the full thickness of 2-by-10 planks should be used. The weakness in wide spacing lies in the strain placed on the planks by this span and in the danger of more than two men standing near the center of the same plank. The uprights are usually of 2-by-4 cross-section turned with the long side perpendicular to the walls of the building and spliced, when necessary, in the same manner as the uprights for the two-post scaffold.

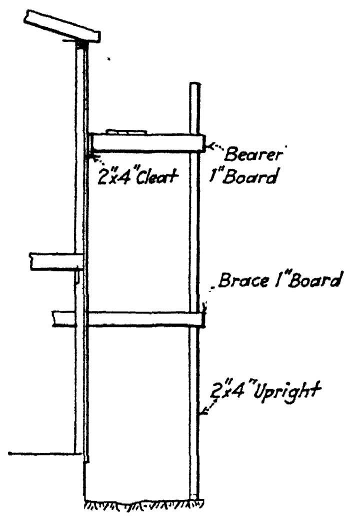


FIG. 248.—Carpenter's scaffold.

The platform is supported by cross-pieces or bearers nailed at one end to the uprights and at the other end to the building. The bearers are similar to those in the two-post scaffold. They are secured to the building by their being nailed to the window frames or to cleats on the wall sheeting. It is preferable to use ledgers, as in the two-pole scaffold, for all heights of scaffold as part of the longitudinal bracing, but it is usual to omit them on low structures, where the uprights are adequately braced by diagonal bracing. The bearers, ties, and all bracing are formed from ordinary ⅞-inch boards. Carpenters frequently employ a bracket or jack secured to the sides of the building for supporting the platform. Such a bracket is shown in Fig. 249.

A *needle-beam scaffold* is widely used by ironworkers, pipe fitters, millwrights and others whose work may be done con-

veniently from platforms suspended by ropes from roof trusses or similar supports overhead. Figure 250 shows a typical needle-beam scaffold. The two beams should preferably be not less

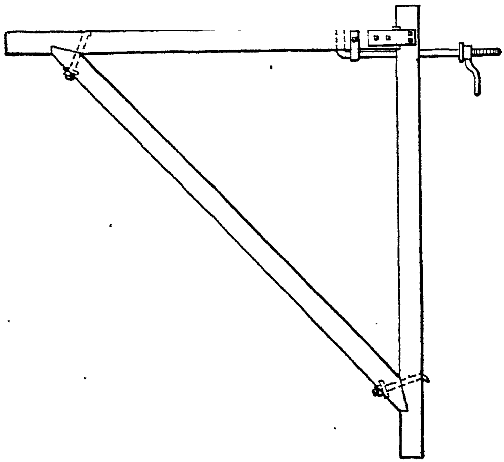


FIG. 249.—Carpenter's scaffold bracket.

than 4 by 6 inches in cross-section and may be suspended by ropes secured to them, as shown in the figure.

The scaffold may be suspended on 1¼-inch diameter ropes from the supports overhead, as pictured in Fig. 250. A scaffold hitch

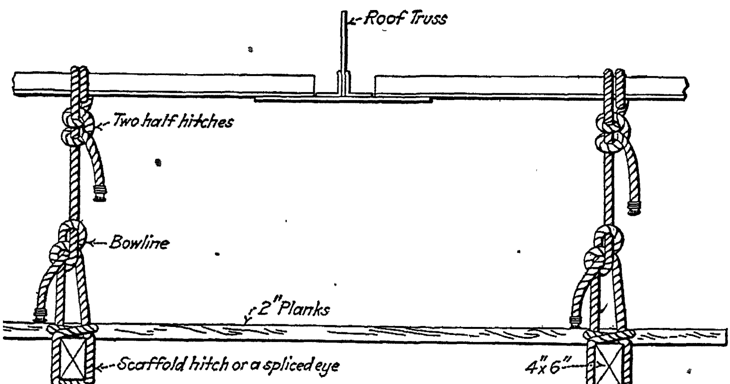


FIG. 250.—Needle-beam scaffold.

around the needle beams will prevent the beams from turning. When the distance from the platform to the supports is not too great, the beams may be hung in several loops of rope passed

around both the beams and supports and tied with a square knot. The scaffold hitch may be conveniently replaced by an eye spliced in one end of the rope. The needle-beam scaffold is more fully discussed under the section devoted to riveting.

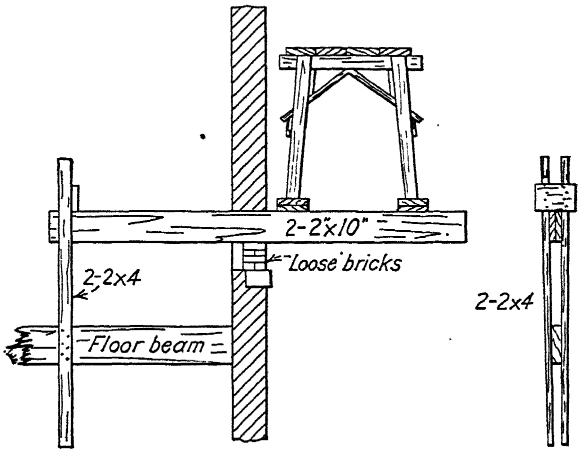


FIG. 251.—Bricklayers' outrigger scaffold.

An outrigger scaffold is most frequently used for constructing the brick walls of buildings having wooden wall-bearing beams. The industrial code and labor union rules require the outrigger to be not less than 3-by-10 inches and not to extend over 6 feet from the outer face of the building. This requirement is met in practice by forming each outrigger of two 2-by-10 planks. The outriggers are placed in the window openings. The usual method of fastening them to the floor joists is shown in Fig. 251.

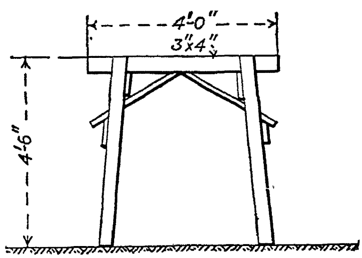


FIG. 252.—Scaffold horse.

A horse scaffold is used by brick masons. The brick are laid to a height about 5 feet above the ground and the horse scaffold is then erected. A wooden horse is about 4 feet 6 inches high and about the same in width. The horses are placed from 7 to 10 feet on centers. Two-inch planks are then laid on the tops of the horses. When it becomes necessary to erect another tier of scaffold, all the planks are removed except the two outside

lines of plank which are left for a support for the second tier of horses. The legs of the horses may be nailed to the planks on which they rest to give greater security against displacement. Horse scaffolds should not be carried over three or four tiers in height. Figure 252 shows a suitable scaffold horse.

Suspended Safety Scaffold.—The suspended safety scaffold consists (Fig. 253) of a plank platform suspended by steel ropes from steel outrigger beams projecting from the side of the building. The outrigger beams are generally located at the roof level

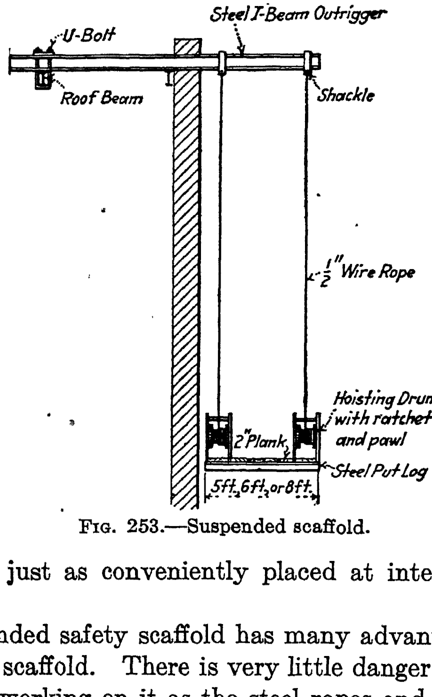


FIG. 253.—Suspended scaffold.

but may be just as conveniently placed at intermediate floor levels.

The suspended safety scaffold has many advantages over the wooden-post scaffold. There is very little danger to life or limb for the men working on it as the steel ropes and steel outrigger and platform supports furnish dependable means of support. The hoisting drums are so constructed as to lock securely and retain their hold on the suspension ropes at all times. There is never any question as to the adequacy of the scaffold bracing as none is required and, consequently, there is no danger of the scaffold being blown down.

There are several other advantages possessed by this type of scaffold. There are no obstructions below or above the scaffold as with a pole scaffold and the ground around the building

underneath the platform can be kept clean and orderly. Bricklayers can lay more brick from this scaffold as they may move freely about without any feeling of danger and, also, because the height of the platform is adjustable and can be kept at the most advantageous height at all times. There is no such loss from broken lumber as occurs in dismantling a post scaffold when the ledgers, bracing, and other parts of a post scaffold are removed.

As a rule suspended-safety-scaffold machines cannot be bought but are rented at a charge of a few dollars for each machine per week from companies making a specialty of this business. The platform planks are not furnished and must be provided by the renter. The rental charge usually includes the services of men to erect the machines.

As may be seen from an inspection of Fig. 253 a scaffold machine consists principally of the following parts: a steel outrigger I-beam, two hoisting drums, two lengths of steel hoisting rope, and a putlog of steel angle irons which supports the platform planks.

The machines may be spaced anywhere from 8 to 10 feet depending chiefly upon the width of the platform and upon whether it will be used for wheeling or carrying materials. The planks should be 2 inches thick and of rough spruce of the best quality. The planks should be long enough to overrun the putlogs about 2 feet on each end. The scaffold may also be equipped with attachments for providing overhead protection, hand rail, toe board, and wind shield.

The suspended safety scaffold is made in three widths so as to provide a platform either 5 feet, 6 feet 6 inches, or 8 feet wide. Each width of platform has its specific advantages. The cost of the 8-foot scaffold is greater than that for the narrower widths, chiefly because an outrigger beam is then formed of two I-beams, instead of one I-beam as in the smaller scaffold. There is also the extra labor of fastening addition U-bolts and other fittings.

A scaffold having a platform 5 feet wide is used on buildings having the usual spacing of floors such as apartment buildings. In such buildings, the materials can be carried out to the scaffold at each floor level. It is not necessary for a bricklayer's tender to pass along the scaffold when carrying materials. With this width of platform, the scaffold machines may be spaced not over 10 feet apart.

The scaffold with a platform 6 feet 6 inches wide is known as a hodding platform. This width of scaffold is suitable where the materials have to be taken up on the outside of building and carried along the scaffold platform in hods. The width provides sufficient additional space for the hod carriers to pass along the scaffold outside the mortar tubs and brick piles. With this width of platform, the machines should be spaced not over 9 feet apart.

The scaffold having a platform 8 feet wide is known as a wheeling scaffold. It is suited to work where the materials have to be wheeled along the platform in wheelbarrows. This width of scaffold is used in the construction of power houses and similar work where there is a great distance between floor levels and, consequently, where the materials have to be elevated in a material tower on the exterior of the structure. The scaffold machines with a platform 8 feet wide should be spaced not over 8 feet apart.

Installation.—The scaffold is easy to install and to operate. The outrigger beams are first placed in position and are anchored securely to the roof or intermediate floor beams by means of U-bolts, as indicated in Fig. 253. The wire suspension ropes are then raised with a hand line and fastened to the outrigger beams by steel shackles. The machines are then ready for the planking. The scaffold platform is easily raised or lowered by manipulating the operating lever on each drum. Each drum is equipped with a ratchet arrangement and pawl for holding the drum stationary.

MATERIAL HOISTING TOWERS

Material hoisting towers are necessary in constructing tall buildings where it is desirable to raise all materials on the outside of the building. Frequently a hoistway is installed in the interior of a building. This is the cheapest arrangement with regard to first cost, as the only temporary construction needed is a head frame erected on the roof. Interior hoists are objectionable, however, as they occupy needed space and may interfere with the progress of the work. A material hoist may be used to elevate concrete, bricks, mortar, partition tile, plaster mortar, radiators, windows and door parts, and other construction materials.

A material tower should be located opposite a vertical row of windows in such a position as to serve the region needing the most materials with the shortest possible haul.

If there is to be a bricklayer's scaffold outside the building, it will be necessary to locate the tower far enough out from the building to clear the scaffold. A distance of 6 to 8 feet in the clear will usually be sufficient. The distance will depend on the width of the scaffold. Landing platforms may be built as needed, extending from the tower to the scaffold and to the floors through

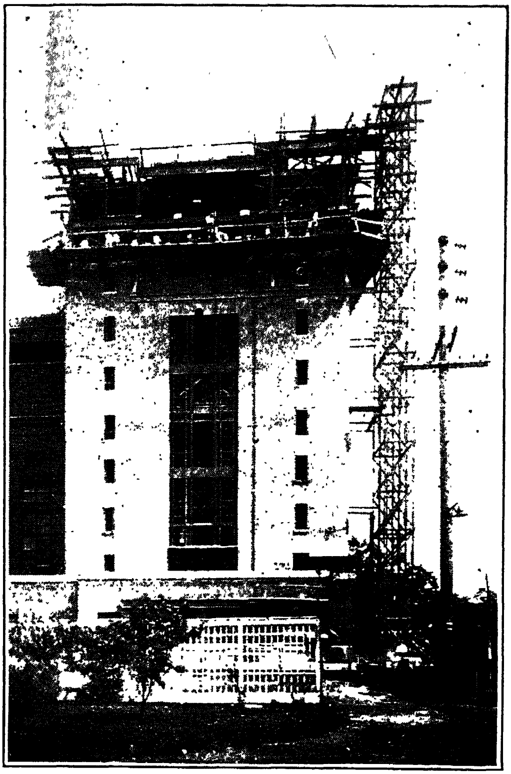


FIG. 254.—A material tower.

the window openings. A tower with landings is shown in Fig. 254. The suspended bricklayer's scaffold in use here is 8 feet wide and the tower was built 10 feet out from the building.

A tower should extend to a height of about 15 feet above the highest point at which a landing will be needed. This clearance above the top landing is needed in case the elevator should be hoisted too high. If 7 feet is allowed for the height of the elevator, there will be 8 feet remaining as a clearance for hoisting.

A tower may be built to accommodate one or more elevators. A single or a double tower will usually be sufficient. A computation should always be made to determine the rate at which materials will be required. Concrete for floor slabs will often have to be hoisted at the same time as bricks and mortar. More than one tower may be needed where the building is of large size or the work is subcontracted to different contractors.

The design and construction of hoisting towers may be varied in different ways. The tops and bottoms of the towers will not

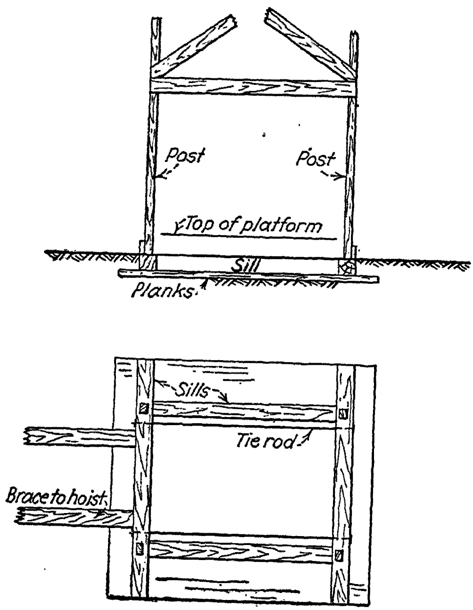


FIG. 255.—Tower base.

vary so much as the arrangement of the bracing and the materials used in the bracing. The towers may be braced by lumber nailed in place or bolted. Towers for chuting concrete may be constructed in the same way as for a material hoist; they are usually self-supporting and they must be more thoroughly guyed than is required when a tower is built alongside of a building.

Tower Foundation.—A foundation for a tower may be formed by placing a layer of planks flat upon the ground. All soft earth and top soil should be excavated from the area to be occupied by the tower. This will bring the planking and sills of the tower

elow the surface of the ground. The excavation should be rranged so that the platform of the elevator will be on a level ith plank runways leading to the tower (see Fig. 255).

Sills.—The sill timbers may be 6 by 6 or 8 by 8 in cross-section. 'hey are laid directly on the plank foundation. The sills will ave to take the pull of the snatch block and the hoisting engine. 'he timbers should be framed so that they can withstand the train effectively. Those that will take the pull of the engine 1ould be tied together with ¾-inch rods. If the hoist is to e located close by, the tower and bed frame of the hoist can be raced by two timber braces between them. If the hoist is to be)cated far away from the tower, each can be anchored separately.

Tower.—The four corner posts of a tower are usually 4-by-6 imbers. A tower two or three stories high may have posts of -by-4 lumber. The posts may be made of 4-by-6 material up o a height of about 120 feet. If a tower is to be higher than 20 feet, it is best to increase the bottom portion to 6-by-6 or ırger timbers. It is preferable to make the posts of timbers f small cross-section, so that they can be easily handled by the 1en building the tower.

Posts are preferably of spruce but may be of fir or pine. Fir ımber is likely to have large knots. This is an objectionable haracteristic. Long leaf pine is a heavy wood and does not rovide such easy nailing as spruce. Lumber containing loose r decayed knots should be discarded. Lumber that has large nots or pin knots extending through it or along one side should ıot be used. The posts are the most important part of a tower nd must be built of sound material.

The posts should be spliced at convenient intervals by pieces of ımber 2 inches thick nailed to all four sides of each post. The cabs should be 3 feet long. The arrangement of the splices is an mportant part of a tower design. They should be arranged so hey do not all come at the same height in the tower. In a single ower with four corner posts, the posts diagonally opposite each ther may be spliced at the same height. The other two posts, lso diagonally opposite each other, may be spliced several feet ıigher or lower than the other two.

Men engaged in building a tower stand on planks laid across he tops of the horizontal braces. Each section of post is lifted y two men and set in place upon the top of the post already in lace. The splice should not be too high above the horizontal

brace or the lifting will be difficult. The distance of splice above the horizontal brace should be about 30 to 36 inches. If this distance is made too small, there will be interference between the diagonal braces and the splice scabs.

The work of erecting a post may be facilitated by using a small pole with tackle, as shown in Fig. 256. The pole is placed in the

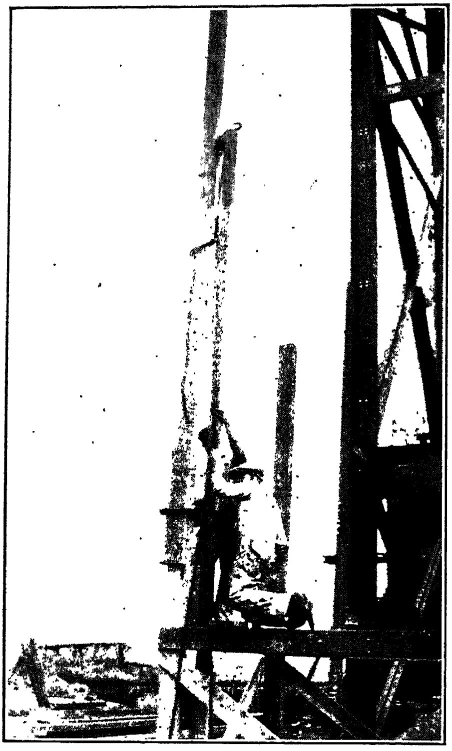


FIG. 256.—Erecting a tower.

corner of the tower and supported on a horizontal brace below. A man on the ground assists the two men on the tower in hoisting a section of post into position. The rigging can be used to hoist other lumber. If a tower is erected alongside of the steel framework of a building, the lumber can be hoisted by a tackle fastened to a timber cantilevering out from the roof tier.

Bracing.—The tower bracing may be either nailed or bolted to the posts. The bolted tower has the advantage that it can be dismantled and stored for subsequent use. The lumber in a

nailed tower is usually well broken up when removed. There are several ways of arranging the bracing in a material tower. Each of these will be described separately but there are features of design that are common to all.

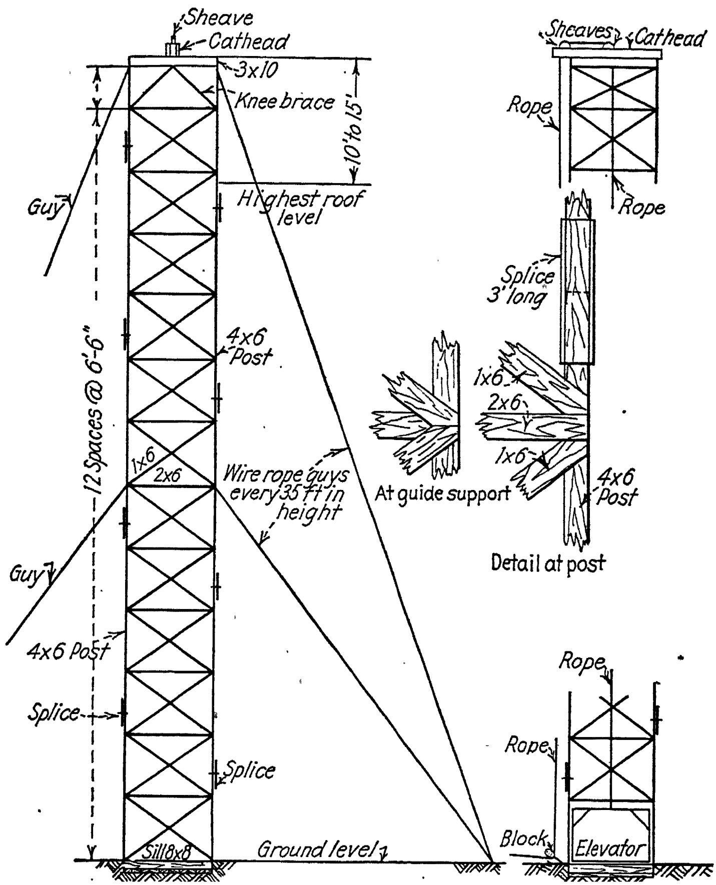


FIG. 257.—Typical tower framing.

If a tower were to be erected without guys or without tying to a building, it would be necessary to design the bracing to withstand heavy wind strains; but the bracing of a tower, as usually built, should be designed to prevent buckling of the posts and buckling of the tower as a whole between braces or guys.

Horizontal Braces.—The horizontal braces should always be 2 inches nominal thickness. They should be thick enough to

serve as a strut in compression, to brace the posts against buckling, and for this reason should not be less than one-sixtieth of their length in thickness. They must also be strong enough to support a working platform for the men engaged in erecting the tower. The horizontal braces should be spaced apart not over forty times the least side of the tower posts. To facilitate

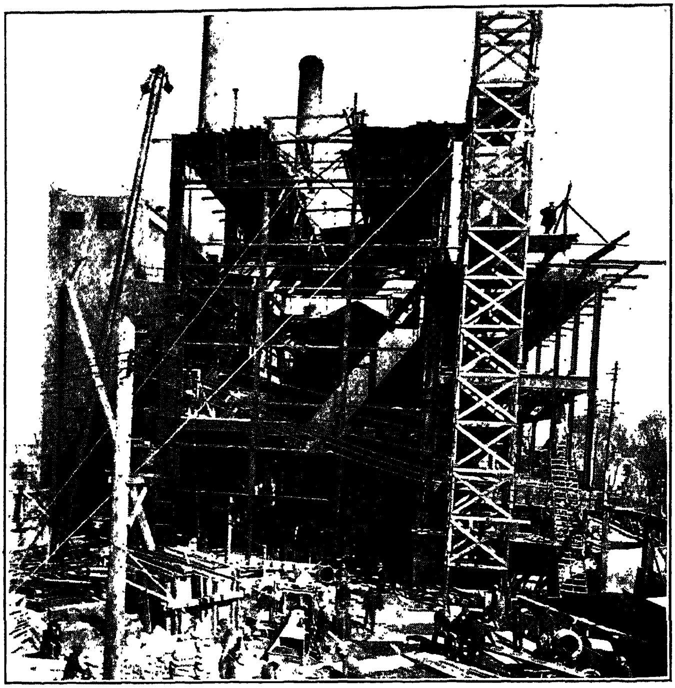


FIG. 258.—A material tower.

erection, the horizontal braces should preferably be spaced close enough together so that a man will be able to nail on a horizontal brace while standing on the brace next below. For this reason, the horizontal braces should not be spaced over 7 feet on centers. A distance of 6 feet 6 inches is better. If a spacing of 6 feet 6 inches is maintained, the spacing of splices on posts can be arranged to better advantage, as three panels of 6 feet 6 inches give a distance of 19 feet 6 inches between splices. This permits the lumber for posts to be ordered in 20-foot lengths. This is a stock size and is not too heavy to handle. The horizontals can

be spaced farther apart than 7 feet if desired and some lumber is saved but the work of erection is made more difficult.

Systems of Bracing.—The diagonal bracing in any nailed tower may be made of 1-by-6 rough spruce. The bracing in a bolted tower should be 2 by 6. Spruce, fir, or yellow pine is acceptable. The bracing may be cut to fit neatly with the edges of the horizontal braces and sides of the tower.

A tower made with all bracing cut neatly is shown in Fig. 257. All braces are cut to a template. The 1-by-6 boards should be nailed with 10 py nails. The 2-by-6 lumber should be nailed with

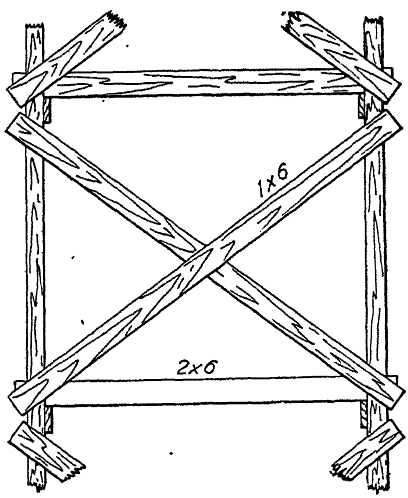


FIG. 259.—Tower bracing.

20 py nails. The 2-by-6 horizontal braces on the sides of the tower behind the elevator guides may be put inside the posts to support the guides. The cross-bracing on these sides is then framed and arranged as shown in the figure. The 2-by-6 horizontals on the other sides are placed on the outside of the posts. It is not necessary to adhere to this arrangement, however, as additional horizontals may be added to support the guides if desired.

A tower may be most quickly built as shown in Fig. 259. The horizontal braces are nailed to the inside of the posts. The braces on one side of the tower are placed just above the braces on the adjacent sides. The cross-braces are nailed to the outside of the posts. With this arrangement there is little interference

between the braces on adjacent sides of the tower and only occasionally will any cutting have to be done. Figure 260 shows a tower of this kind that was built quickly around a smokestack to make necessary repairs.

A bolted tower is sometimes desirable, as it can be dismantled and erected again on other jobs. The braces are all 2 by 6 and are fastened to the posts with ½- or ⅝-inch bolts. The bracing

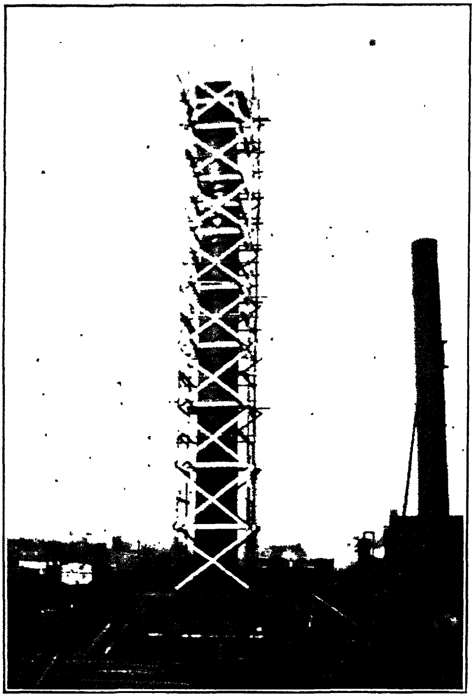


Fig. 260.—A tower.

on adjacent sides should be arranged to meet on the same post as shown in Fig. 261. The bolts should be staggered so as to miss each other in passing through the post.

Guides.—The guides for the elevator should be made preferably of long leaf yellow pine surfaced smooth on all four sides. The guides may be made of 4-by-4, 3-by-6, or 4-by-6 lumber. There is a tendency for an elevator to bend the guides out of line when passing up and down; so it is preferable to have the guides large in cross-section. For this reason, it is preferable to use 4-by-6 lumber. The bottoms of the guides should rest on the

sills. The guides should be bolted fast with ½-inch carriage bolts. The sections of each guide should be spliced as shown in Fig. 262. The horizontal braces can be utilized to act as sup-

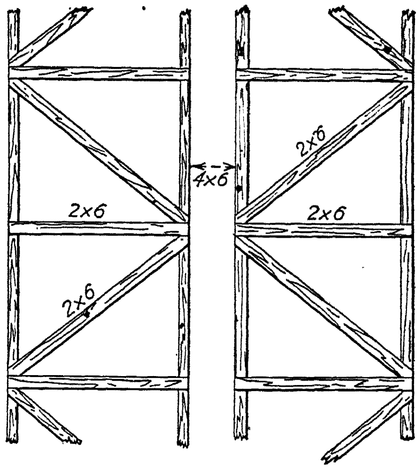


FIG. 261.—Bracing for a bolted tower.

ports for the guides. Care must be taken to make these braces safe against lateral bending. If the supports are weak, or placed too far apart, they may bend outward and permit the elevator to cant out of plumb. This is most likely to occur when the

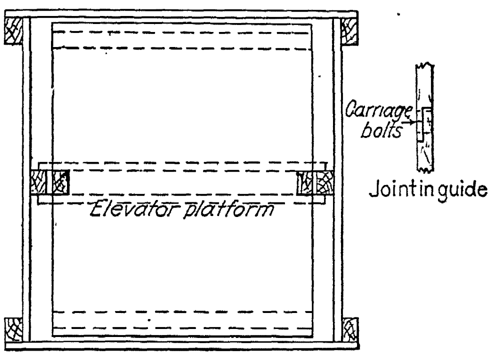


FIG. 262.—Elevator guides.

elevator platform is loaded unevenly and usually results in the elevator jamming between the guides.

Top of Tower.—The tower should end at the top with a ring of timbers 3 inches thick resting directly on the top of the posts.

These timbers usually are 10 or 12 inches in depth. They support the cathead containing sheaves for the elevator cable.

The timbers should rest on the posts and be secured to them with scabs, spiked or bolted fast. As an additional support for the cathead, knee braces may be added as shown in Fig. 257. The top of a tower in use is shown in Fig. 263.

Cathead.—The wire rope operating the elevator is fastened to the top of the elevator and extends upward in the center of the tower to a sheave in the cathead, thence to another sheave in the

FIG. 263.—Top of a tower.

cathead, so located that the rope will clear the side of the tower in passing downward along the outside of the tower. In passing from the top of the tower to the hoisting engine the rope should pass over a single sheave fastened to one of the sill timbers. If a tackle block is used for this purpose, it should be held suspended at all times in position by a wire fastened to the shell of the block.

The cathead at the top of a tower for one elevator contains two sheaves as shown in Fig. 263. The cathead for a double tower should contain four sheaves. The sheaves should be self-lubricating and turn on the pin. The pin can be fastened to the

timbers by pieces of flat iron bent over it and spiked to the beams. One sheave should be located to take the rope from the elevator in the center of the tower, the other sheave so as to hold the rope out away from the side of the tower. The cathead should be braced from overturning sideways by steel strap braces spiked to the top of the tower. The sheaves and pins in the cathead should be inspected frequently for signs of wear and possibility of failure.

Elevator.—A typical elevator for a material hoisting tower is shown in Fig. 264. An elevator made of wood with steel bracing

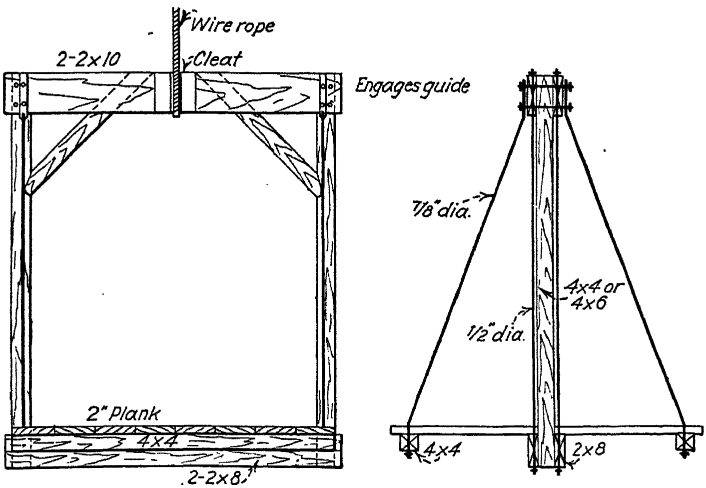


FIG. 264.—Elevator.

is better for construction work than one of steel. It can be repaired more quickly if it becomes damaged, as it is likely to be should it be allowed to hit the landing with too much force.

In preparing to build a tower, the first consideration should be given to the size of the elevator platform. It should be large enough in each direction to accommodate the articles to be placed on it. For concrete work, it should be made wide enough to allow two concrete barrows or carts to be placed side by side on it. A platform about 6½ feet square is a convenient size.

Substitutes for a Tower.—A bricklayer's scaffold outside a building can be converted into a hoisting tower with little labor. The concrete in the floors and roof of a small building can be hoisted in barrows and taken through the windows without the assistance of an elevator platform. Four posts of the scaffold are

extended about 10 feet above the roof level. A cathead may be arranged at the top of the posts or a single tackle block can be lashed to a timber laid across the tops of the posts. With this arrangement a concrete cart or wheel barrow can be hoisted to any floor and drawn into the building by hand. The top sheave or tackle block should be high above the landing so that there will be rope enough to allow the load to be pulled over.

When necessary, an outrigger erected on the roof can be used for hoisting concrete in small quantities. A gin pole erected close to a building can be used for the same purpose but the top of the pole should extend well above the landing place for the concrete. A jigger boom can be improvised and attached to the gin pole with little extra labor.

CHAPTER XI

ERECTION AND RIGGING

Hemp Ropes.—The details of this important branch of construction work are so intimately connected with the use of ropes that a familiarity with their formation and with the various knots, hitches, bends, and ties employed in ropework is indispensable. It is necessary to know how to form the ties and to fix in mind the particular purposes for which each tie is especially suited.

All cordage ½ inch in diameter and over is called rope. Rope sizes may be stated in terms of diameter or of circumference. Both methods are in common use. Sailors and pile-driving men usually use the circumference in mentioning sizes; erection men and others engaged in construction work usually speak of sizes in terms of diameters. It is correct to designate the size either way but in purchasing rope, care should be taken to specify which dimension is intended.

Ropes are commonly made of hemp. While any vegetable fiber prepared for commercial use is called hemp, the ropes used on erection work are commonly made of manila hemp. In forming a rope, a number of hemp fibers are laid together and twisted loosely with a right-hand twist into what is called a "yarn"; several yarns are then twisted together in a left-hand direction, forming a rope strand and several strands in turn are twisted together in a right-hand direction, forming the rope. This reversing of the twist in each operation brings the fibers into positions parallel to the axis of the rope, and adds greatly to the effectiveness of their strength. Rope is formed of either three or four strands. The three-strand rope is the one in common use; four-strand rope is extremely pliable but has a strong tendency to kink.

A good manila rope is hard and pliant and is yellowish- or greenish-gray in color with a noticeable luster. A few months of exposed work will cause a considerable loss in strength and, for this reason, an old rope should be inspected before being used

by twisting the rope in such a manner as to part the strands and expose the interior of the rope to view.

Rope should always be coiled clockwise. To avoid kinks in uncoiling the rope, the end first laid down should be pulled up through the center of the coil. If a rope kinks in uncoiling it, the coil should be turn over and the other end should be pulled out of the coil.

The table of strengths given below is for new rope and is based on strengths adopted by rope manufacturers, modified slightly in some cases to agree with more conservative figures used by erection companies and other authorities experienced in the use of ropes.

TABLE 10.—STRENGTHS OF MANILA ROPE

(Safety Factor-4)

Size of circumference, inches	Size of diameter, inches	Breaking strain, pounds	Safe load, pounds	Safe load, tons
1½	½	2,000	500	¼
2¼	¾	4,000	1,000	½
2¾	⅞	6,000	1,500	¾
3	1	8,000	2,000	1
3½	1⅛	10,000	2,500	1¼
4	1¼	12,000	3,000	1½
4¼	1⅜	14,000	3,500	1¾
4¾	1½	16,000	4,000	2
5½	1¾	24,000	6,000	3
6	2	30,000	7,500	4

Quick Computation of Strength.—It is a great convenience to know the safe carrying capacity of any manila rope without having to consult a book or a table of rope strengths. It will be seen from an inspection of the above table that the safe load in tons for any diameter of rope is approximately equal to the diameter in inches squared. A number is squared when it is multiplied by itself.

To find the safe capacity of any rope, its diameter is measured and this dimension is squared. For example, if the rope is 1¼

inches in diameter, $1\frac{1}{4} = \frac{5}{4}$. Squared, $\frac{5}{4} \times \frac{5}{4} = \frac{25}{16} = 1\frac{9}{16}$ tons. The following original formula may be used.

$$\text{Manila rope safe load in tons} = D^2$$

Knots.—When a rope is laid down, as in Fig. 265, the different portions of the rope are designated as indicated in the figure.

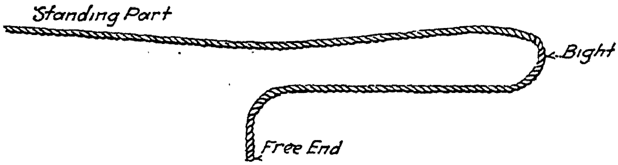


FIG. 265.—Parts of a rope.

The main portion of the rope is called the standing part, the double part where bent into a loop is termed a "bight," and the

FIG. 266.—Square knot.

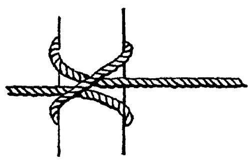


FIG. 267.—Clove hitch.

extremity of the rope the free end. These three parts form the foundation for all knots, hitches, bends, and ties.

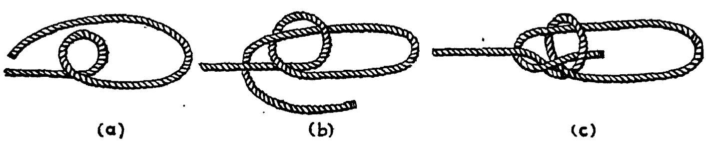


FIG. 268.—Bowline knot.

The words "knots," "hitch," and "bend" are so overlapping in meaning in present-day use that it is useless to try to distinguish the one from the other by any hard-and-fast definitions; it is sufficient for all ordinary purposes to know the name commonly applied to each. A knot, bend, or hitch when made in the correct way will not slip when under strain and is quickly and easily untied.

The *square knot*, shown in Fig. 266, is the common knot known to almost everyone. It is frequently tied incorrectly unless care is taken to form it in the correct manner. It should be noticed

that, when correctly tied, the standing part and free end of one rope lie side by side and parallel in the bight of the other rope. This knot is much used to tie ropes together and to finish lashings, as shown in Figs. 282, 295, and 316. It is a very simple and serviceable knot and may be depended upon when subjected to a severe strain.

The *clove hitch* is shown in Fig. 267. It is very easy to tie and is one of the hitches most frequently used. It is much used in fastening guy ropes to gin poles, as in Fig. 295, and to form a tie to a post. Also, it is the basis for the formation of many of the other useful knots and hitches. When strained this hitch tightens and takes a firm hold. The clove hitch will not slip sideways and is useful for tying to a timber or for securing a sling to a vertical post or rod to serve as fastening for small tackle.

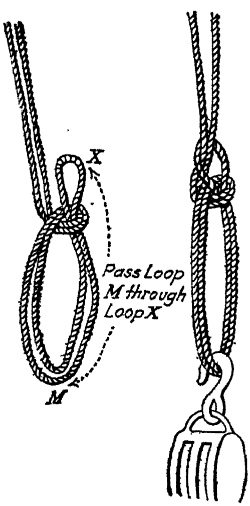


FIG. 269.—Bowline-on-a-bight.

The *bowline knot* is a trifle hard to learn but when mastered it is quickly tied and will not slip or jam when under a strain. It is easily untied. This knot is shown in Fig. 268. To tie it a hitch is first formed in the standing part, as shown at *a*; the free end is then run through it and around the standing part, as shown. The bowline knot is always used at the end of a rope. It will be found useful for forming a loop into which the hook of a tackle block may be hooked or it may be used for tying to a post. The *bowline-on-a-bight* may be tied at any spot along the length of a rope and is useful for taking the hook of a tackle or may serve as a bos'n chair (Fig. 269).

The *half hitch* and the *overhand knot*, shown in Figs. 270 and 271, are used mainly in the formation of other knots and hitches.

The "*cat's-paw*," shown in Fig. 272, is very strong and efficient and is an ideal means of fastening the hook of a block into a rope or fall. The cat's-paw may be formed anywhere in the length of the rope or at the end. The cat's-paw cannot fail by slipping when strained and possesses, besides, the advantage that it provides a double-bearing surface for the hook. To form a cat's-paw, a bight of the rope is thrown across the standing part

(Fig. 272). Both sides of the bight and the standing part are then grasped at the middle of the bight. The parts grasped are turned at right angles to the rope and then rolled several turns upon the standing part. The two loops thus formed are then placed upon the hook. The cat's-paw is quickly untied by removing it from the hook and shaking out the loops. Either the

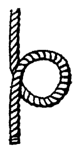


FIG. 270.—Half hitch.

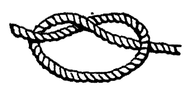


FIG. 271.—Overhand knot.

cat's-paw or the bowline-on-a-bight can be tied anywhere along a rope to provide a purchase for a luff tackle.

The *neck hitch or blackwall*, shown in Fig. 273, is another method of fastening a rope to the hook of a tackle block. Like the cat's-paw, it may be used anywhere along the length of a rope. It is

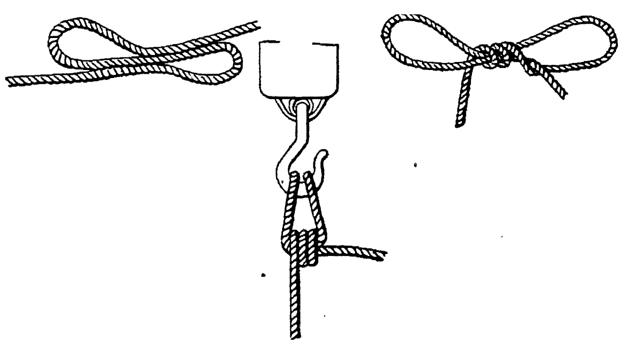


FIG. 272.—Cat's-paw.

very quickly formed and is frequently used. While not as trustworthy or as strong as the cat's-paw, it seldom slips or gives way. The neck hitch is a great timesaver and is very convenient to use in moving machinery.

The *racking hitch*, shown in Fig. 274, is also a method of fastening a rope to the hook of a block. It is a strong hitch and is a very effective means for shortening a sling and at the same time fastening it to a hook. The racking hitch is often called a cat's-paw.

The *stopper hitch*, shown in Fig. 275, will not slip sideways and is much used to fasten tackle to manila-rope guys to tighten

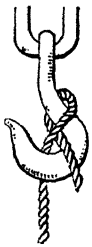


FIG. 273.—Neck hitch or blackwall.

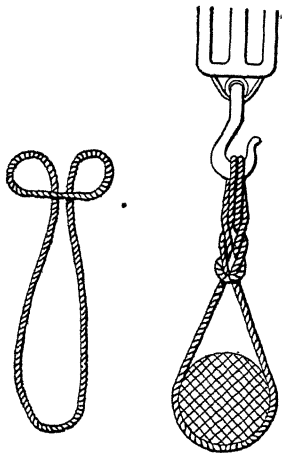


FIG. 274.—Racking hitch.

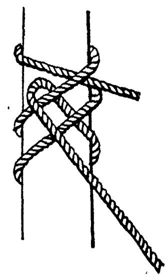


FIG. 275.—Stopper hitch.

them, as indicated in Fig. 302. This is by far the best hitch to employ for fastening a hoisting tackle to a vertical rod or post.

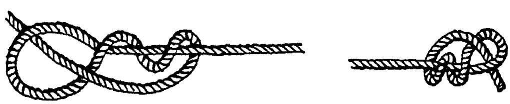


FIG. 276.—Stevedore knot.

The *stevedore knot* (Fig. 276) may be used to fasten a rope to the becket of a tackle block or to a ring or other eye-shaped object. To tie it, the free end is carried twice around the standing part and is then passed back through the bight thus formed.

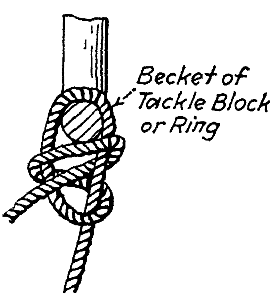


FIG. 277.—Becket hitch.

The *becket hitch* is shown in Fig. 277. The becket hitch, as its name implies, is much used to fasten a rope to the becket of a tackle block. It consists of a turn through a becket and a clove hitch. It is quickly formed and is easily untied, but will never slip. It is a clove hitch distorted slightly.

The *timber hitches* (Fig. 278) are used in handling timbers. The one at *A* is very quickly applied and when used in conjunction

with the half hitch as at *B*, it is particularly adapted to pulling timbers endwise.

Three ways are shown in Fig. 279 to fasten a rope to a ring or chain link; the one at *B* is often used to fasten a rope to the becket of a tackle block.

The *marlinespike* hitch is shown in Fig. 280.

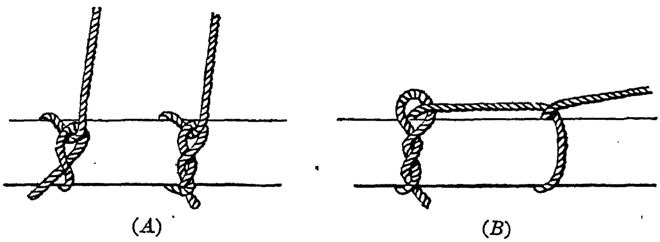


Fig. 278.—Timber hitches.

A *seizing* is a lashing used to bind the free end of a rope to the standing part. To form it, a piece of yarn is fastened near its center to the standing part of the rope with a clove hitch. Each part of the yarn is then carried around both parts of the rope in opposite directions. They are tied together with a square knot.

A *mousing* (Fig. 281) is a lashing which serves to close the mouth of a hook. It prevents displacement of a rope, as well as strengthens the hook against spreading. To form it, a mousing is started by tying a piece of yarn to the shank of the hook with a clove hitch at the center of the yarn. Each part of the yarn is passed several times around the mouth of the hook in opposite directions, finishing with a square knot.

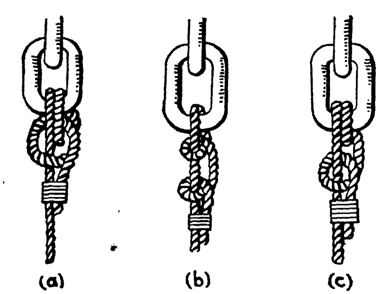


Fig. 279.—Eye fastenings.

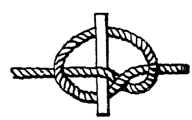


Fig. 280.—Marlinespike.

A *lashing* (Fig. 282) consists of several turns of rope wound around an object in such a manner as to provide a means by which the object may be lifted with tackle. To make a lashing, a piece of heavy rope is procured, which is long enough to make at

least six turns around the object with enough surplus to form a knot.

The piece of rope is laid across the object at the middle of the rope. One end of the rope is then carried around the object

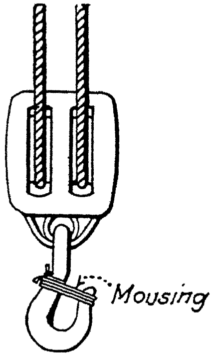


FIG. 281.—Mousing.

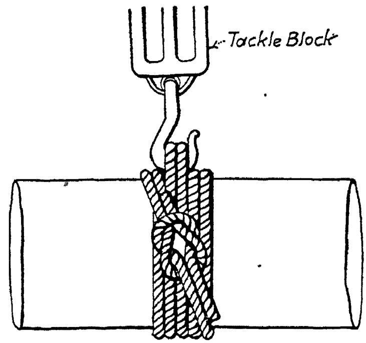


FIG. 282.—Lashing.

several turns, each turn being wound snugly against the turn before and pulled tight. The other end of the rope is then passed around the object an equal number of turns, making six or more turns. Both ends of the rope are then brought diagonally across the lashing and tied with a square knot. The hook is preferably inserted so as to engage two or three of the middle turns. This will permit the turns of the lashing at each end to pull up tight and grasp the object securely when it is raised.

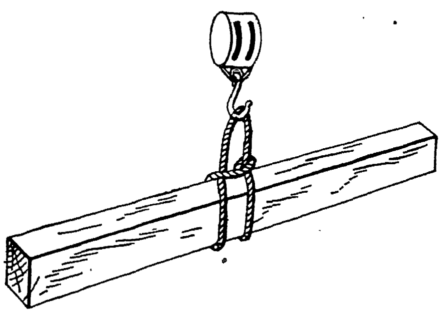


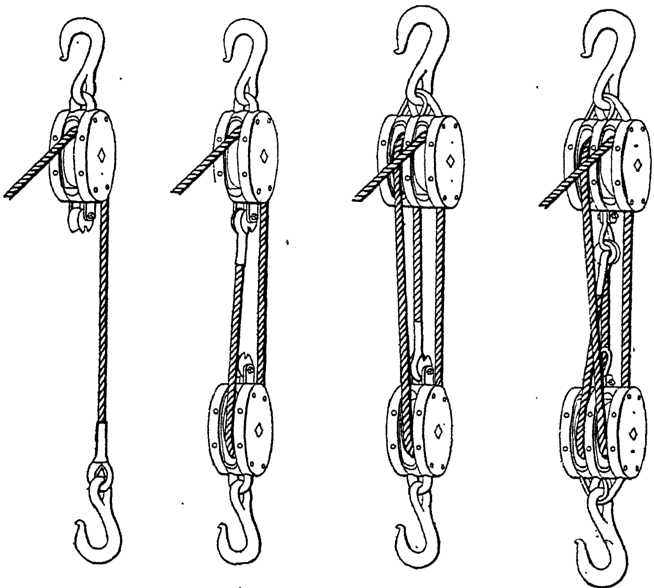
FIG. 283.—Sling.

A sling (Fig. 283) when made of manila rope should be fashioned from larger-sized rope than that used in the hoisting tackle. It is essential that the strength of the sling should be equal to the task of carrying the load. This may be roughly computed

by the capacity of the parts of rope engaged by the hook or shackle with an allowance for the cutting action of the hook upon the rope. For this reason, single slings should be placed on the hook, as shown in Fig. 274, or with some similar hitch.

TACKLE

A hoisting tackle is shown in Fig. 284. The term "tackle" applies to the entire assemblage of ropes and tackle blocks com-



(a) (b) (c) (d)

FIG. 284.—Hoisting tackle.

plete. The end of the rope to which the power is applied is called a "fall." Both blocks of a tackle are ordinarily provided with hooks by which they may be attached to an object. The upper, or stationary block, is always fastened to some support and remains immovable; the lower and moveable block is fastened to the object to be hoisted and, in the operation of hoisting, moves upward lifting the load with it.

One of the blocks of a tackle should be provided with a becket for the purpose of making fast one end of the tackle rope, as shown in Fig. 284. When neither of the tackle blocks is provided with a becket the end of the rope may be made fast to the shank of one of the hooks as a makeshift arrangement.

Assembling Tackle.—To assemble a tackle, the rope has to be passed through the openings in the blocks and over each sheave successively and then made fast to the becket. In reeving the rope through the blocks, it should be kept in mind that the end of the rope will be reeved first over all the sheaves in both blocks and will then, finally, be made fast to the becket.

It must be decided from which block the fall end of the rope is to run. A study of the diagrams in Fig. 284 will make this clear. These all show the usual arrangement with the fall leaving the sheave of the upper or fixed block, though it might be necessary to have the fall leave from the moving block as in the hoisting tackle on a derrick boom (see Tables 22 and 23). In a tackle with two double blocks, it will be noticed that the becket is on the upper or fixed block; in the tackle with a double and a single block, the becket is on the single block.

In detail the tackle is assembled as follows: The blocks should be placed with their shells flat upon the ground, 4 or 5 feet apart, with the hook ends of the blocks pointed away from each other and with hooks turned either up or down as may be necessary to bring the lead line from any snatch block or winch in the proper direction to the tackle blocks. The coil of rope should be placed on the far side of the blocks away from the person who is to reeve the rope through them. The becket end of the rope is passed first through the lowest sheave of the block from which the fall is to run and is carried over to the other block, passed through and around the lower sheave of the second block and back to the next sheave of the first block and so on, until it can be made fast to the becket. The rope may be made fast to the becket in any of the ways shown in the figures. The becket hitch, illustrated in Fig. 277, is that used by professional riggers. It is a convenient method and also very dependable. The tie, shown in Fig. 279 at *b*, is in general use on almost every construction job in the country, the rope is secured by two half hitches around itself and a seizing. The seizing should never be omitted. An eye spliced in the end of the rope serves admirably for the same purpose.

When triple blocks are used, the reeving of the rope through the blocks is usually done differently. The rope is passed over the sheaves so that the fall will leave the top block from the center sheave. This makes the blocks hang evenly as the fall part of the rope, that which has the heaviest pull, lies between

parts having less strain. A tackle of triple blocks is shown in Fig. 285. Blocks with over three sheaves are seldom used with manila rope as greater lifting power can be more conveniently obtained by the use of wire hoisting rope.

It is general practice to use an equal number of sheaves in both upper and lower blocks, or to have one more sheave in the upper block than in the lower block.

Changing Number of Parts.—Where blocks having several sheaves are employed to hoist a load, the speed of hoisting is slow. When light loads are lifted with the tackle, it is frequently desirable to gain greater speed by using fewer parts of line between the blocks. This can be easily done by taking the rope off the becket and fastening it around one of the sheaves of the other block, securing it as a noose by means of a shackle (see Fig. 286). When more parts of line are again desired, the shackle with rope attached can be pulled down and the rope can again be made fast to the becket in its original position. This method of changing the hoisting speed and capacity of tackle is particularly useful in working with derricks on steel erection.

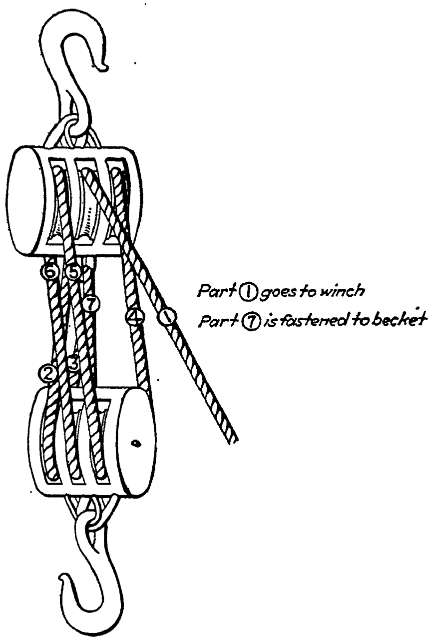


FIG. 285.—Reeving of triple blocks.

Lifting Capacity.—The lifting capacity of a tackle equipped with a rope of any specified size will vary with the number of sheaves in each block. The greater the number of sheaves the greater will be its lifting capacity. By one fixed block as at *a* in Fig. 284 no increase in power is gained. The only advantage is a change in direction of the applied power. To gain power, it is necessary to have a movable block. At *b* the block is movable and the lifting power is doubled. In other words, to raise the

same load in *b* only one-half as much power need be applied to the fall as in the case at *a*. In *a* each part of the rope takes the full weight of the load. In *b* the weight borne by the rope is divided equally by the two parts supporting the movable block. So also at *c* where the upper fixed block has two sheaves and the lower movable block has one sheave, the lower block is supported by three parts of rope which divide the burden between them.

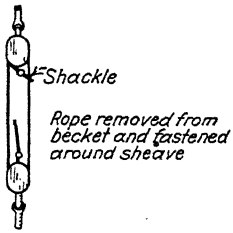


FIG. 286.—Changing number of parts.

This equal division of the load between the parts of rope only obtains when the load is suspended at rest. Thus far, no consideration has been given to the effects of friction. It is common practice to figure the capacity of a tackle in this way, by disregarding friction and accepting the theoretical values obtained in assuming that the strength of any tackle is equal to the strength of the rope multiplied by the number of parts of rope supporting the lower block. To illustrate by example, if a 1-inch rope is used in Fig. 284, and the strength of 1-inch rope is taken as 1 ton, the theoretical capacity of the tackle at *c* is Capacity = 1 ton × 3 parts = 3 tons.

TABLE 11.—SUITABLE WORKING LOAD FOR A PAIR OF WOOD BLOCKS WITH FLATTED HOOKS

Length of shell, inches	Diameter of rope, inches	Singles, tons	Doubles, tons	Triples, tons
Regular Blocks, with Loose Hooks				
6	¾	½	1	1
8	⅞	1	2	3
10	1	2	4	6
12	1⅛	4	8	12
Wide Mortise, with Loose Hooks				
8	1	1	2	4
10	1¼	4	6	8
12	1⅜	8	12	16

When hoisting, however, the friction of sheaves and ropes has to be overcome. The part of rope which is fastened to the becket is the only part which does not have to overcome its share of the friction as well as support its share of the load. Each part of rope, progressing from the becket toward the fall end or lead line, has to overcome increasing amounts of friction, the fall end itself being compelled to overcome the friction in all parts of the tackle. Snatch blocks and additional sheaves outside the tackle proper, over which the lead line must pass, cause additional losses of power. The actual lifting capacity of the tackle then depends upon what proportion of the strength of the lead line is available for lifting the load after overcoming all friction.

TABLE 12.—RELATION OF BLOCKS, ROPES, AND HOOKS

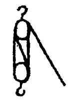
Length of shell, inches	Diameter of rope, inches	Metal of hook, inches		
		Single block	Double block	Triple block
6	3/4	3/4	7/8	1
7	3/4	7/8	1	1 1/8
8	7/8	1	1 1/8	1 3/8
10	1	1 1/4	1 3/8	1 1/2
12	1 1/4	1 3/8	1 1/2	1 5/8
14	1 1/2	1 1/2	1 5/8	1 3/4

The following table (Table 13) of *lifting capacities of tackle* takes into account this loss by friction. Table 13 gives safe lifting capacities of tackles without snatch blocks. Table 14 gives safe lifting capacities of tackles when two snatch blocks are used These tables may be safely used for selecting tackle for hoisting purposes. The values given in the table are conservative and are for new manila rope. Where old or worn rope is to be employed allowance should be made for the condition of the rope. Tables 13 and 14 are based on tests made by the author for the purpose of determining losses due to friction.

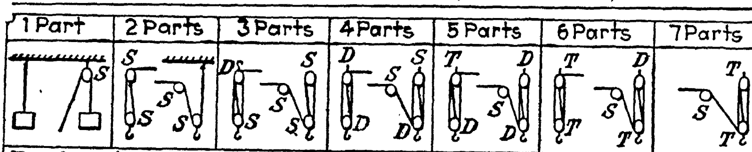
For *ordinary erection work,* where a load of 1 or 2 tons has to be lifted, a tackle formed of two 10-inch double blocks and 1 inch manila rope is most suitable and is the rig in general use for this load. It is always advisable as a precautionary measure, to

have the tackle amply strong for the work to be done. The operation of hoisting is accomplished much more smoothly if the tackle is overly strong. For example, if a weight of 5 tons has to be lifted, it is much better to use a tackle with a capacity of 6 or 7 tons for the work than to select one which would be worked close to its safe capacity.

TABLE 13.—SAFE LIFTING CAPACITY OF TACKLE
(Without Snatch Blocks—Manila Rope,
Wooden Shell Blocks with Hooks)



Tons	7-inch blocks ¾-inch diameter rope	10-inch blocks 1-inch diameter rope	12-inch blocks 1¼-inch diameter rope	14-inch blocks 1½-inch diameter rope
¾	2 parts			
1	3 parts	2 parts		
2	6 parts	3 parts	2 parts	
3	......	4 parts	3 parts	
4	......	5 parts	3 parts	2 parts
5	......	6 parts	4 parts	3 parts
6	......	......	5 parts	4 parts
7	......	......	6 parts	4 parts
8	......	......	7 parts	5 parts
9	......	......	......	5 parts
10	......	......	......	6 parts
11	......	......	......	7 parts
12	......	......	......	7 parts



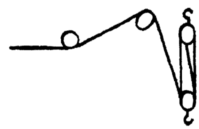
To get number of parts add number of sheaves

Tackles with two 7-inch double blocks rove with ¾-inch diameter rope are, in general, used as auxiliary tackle for tightening guy lines, increasing the pull on larger falls, and for hoisting very light loads.

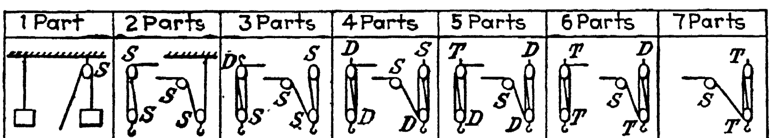
Before a tackle is assembled, the rope and blocks should be examined for defects; rope that has deteriorated from age or exposure should not be used. The blocks may contain sheaves that are cracked or hooks that are spread or possess similar defects which will debar their use for important work. During the operation of hoisting, the foreman should watch the blocks with great care to avoid getting the blocks jammed against each other at the limit of travel, block to block, as it is sometimes called. Such a circumstance is likely to end in disaster if allowed to occur.

TABLE 14.—SAFE LIFTING CAPACITY OF TACKLE

(With Two Snatch Blocks on Lead Line—Manila Rope, Wooden Shell Blocks with Hooks)



Tons	7-inch blocks ¾-inch diameter rope	10-inch blocks 1-inch diameter rope	12-inch blocks 1¼-inch diameter rope	14-inch blocks 1½-inch diameter rope
¾	2 parts			
1	3 parts	2 parts		
2	6 parts	3 parts	2 parts	
3	....	4 parts	3 parts	3 parts
4	....	6 parts	4 parts	3 parts
5	....	....	5 parts	3 parts
6	....	....	7 parts	4 parts
7	....	....	....	5 parts
8	....	....	....	7 parts



To get number of parts add number of sheaves

TACKLE BLOCKS

Tackle blocks made with wooden shells are commonly used with manila rope. Blocks with iron shells, that are designed

for use with manila rope, can be obtained if desired. Figure 287 shows a single, a double, and a triple wooden-shell block, each

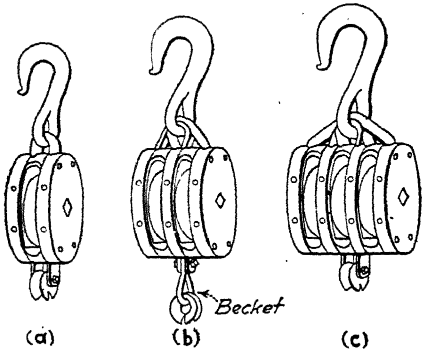


FIG. 287.—Wooden shell blocks.

with a becket. It should be noted that the sheaves, preferably with roller bearings or self-lubricating, revolve upon a steel pin. The pin is supported by iron straps which are engaged by the base of the hook. Any pressure coming upon a sheave from a rope is transmitted to the pin and through the straps to the hook. It will be seen that the wooden shells or cheeks simply act as a casing to the working portions of the block and to guide the rope into the sheaves.

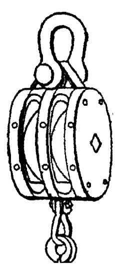


FIG. 288.—Wooden shell block with shackle and becket.

The hooks of tackle blocks are usually turned at right angles to the general direction of the sheaves. This fact, seemingly trivial, is worth retaining in mind, as it has a bearing upon selecting desirable locations for snatch blocks, winches, and the like to which the fall will run after leaving the sheaves of the block. Also, as suitable places for stationing a winch often have to be accepted wherever they happen to be located, the tackle will have to be rove right hand or left hand as the case may be, so that the rope can extend directly to them. Blocks with swivel hooks make these precautions unnecessary. Tackle blocks may also be obtained which are fitted with a lashing shackle instead of a hook. A shackle is much stronger than a hook and is particularly adapted for heavy work where the shackle may be used to engage several turns of a lashing or a chain when lifting a heavy load.

Snatch Block.—A snatch block (Fig. 289) is a single block which can be opened on the side to receive the bight of a rope, the block having a space between the top of the sheave and the base of the hook which may be opened to receive the rope. This opening is closed after insertion of the rope by a link which is fastened to the body of the block and engages the base of the hook in such a manner as to complete the structure of the block. Snatch blocks are fitted with swivel hooks which allow the blocks to be turned freely in any direction. They are employed entirely as unmovable blocks, and no increase of power is gained by them. They are a means for changing the direction of the fall running from a tackle block to a winch, engine, or other source of power. They are in frequent use at the foot of gin poles, shears, derricks, and in similar positions, often two or three snatch blocks being used on a single lead line.

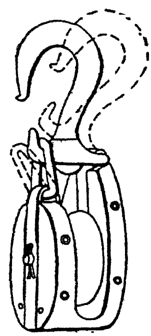


Fig. 289.—Snatch block.

WIRE-ROPE TACKLE

Wire Rope.—A wire rope is composed of six strands, each strand containing either 7 or 19 wires to the strand. Wire hoisting rope is laid up around a hemp center. Hoisting rope is

TABLE 15.—STRENGTH OF STANDARD WIRE HOISTING ROPE—CRUCIBLE CAST STEEL

(Six Strands of 19 Wires Each and a Hemp Center)

Diameter, inches	Breaking strength, tons	Safe load, tons
3/8	5	1
1/2	8	1 3/4
5/8	13	2 1/2
3/4	20	4
7/8	26	5
1	34	7

made of strands containing 19 wires. The seven-wire strands make a stiff rope which is only useful for guying purposes. Steel guy rope is usually galvanized as a protection from the weather.

Steel hoisting rope is left untreated except for a protective coating of oil or grease. The strands of fine wires together with the central core of hemp result in a hoisting rope of extreme pliability.

Several varieties of steel wire hoisting rope are manufactured, the principal ones being those known as "plough-steel rope" and "cast-steel" hoisting rope. The plough-steel rope is the strongest, as may be seen from an inspection of the tables. It is also the most expensive.

TABLE 16.—STRENGTH OF STANDARD WIRE HOISTING ROPE—PLOUGH STEEL

(Six Strands of 19 Wires Each and a Hemp Center)

Diameter, inches	Breaking strength, tons	Safe load, tons
3/8	6	1
1/2	10	2
5/8	15	3
3/4	23	4 1/2
7/8	29	6
1	38	7 1/2

To uncoil or to coil wire rope, the wooden reel or spool on which the rope is wound should be mounted on a spindle so as to revolve freely; the rope is paid off as the reel is revolved. When the rope is not mounted on a reel but is in a coil, the coil should be rolled on the ground and the rope should be paid off in that manner.

Strengths of wire hoisting rope both cast steel and plough steel are given in Tables 15 and 16. These strengths can be easily computed with sufficient accuracy for any case by the following formulas which may be tested for accuracy by comparison with the values given in the tables. The results obtained by the use of these formulas are safe loads stated in tons with a safety factor of 5.

Plough-steel rope, safe load in tons = $8D^2$, or eight times the diameter squared.

Cast-steel rope = $7D^2$, or seven times the diameter squared.

Where D = diameter in inches.

As a practical example, to compute the safe load to use with a new plough-steel rope $\frac{3}{4}$ inches in diameter: From above formulas, safe load $= 8 \times \frac{3}{4} \times \frac{3}{4} = \frac{72}{16}$, or $4\frac{1}{2}$ tons.

TABLE 17.—SIZES OF WIRE-ROPE BLOCKS AND ROPES

Diameter of rope, inches	Outside diameter of sheaves, inches
½	10
⅝	12
¾	14

The above formulas are very similar to those for manila rope and may easily be committed to memory.

Tackle Blocks for Wire Rope.—Tackle blocks for wire rope are made entirely of iron or steel. They may be obtained incased in

TABLE 18.—SAFE CAPACITY OF HOOKS
(Safety Factor-5 Based on Tests)

Diameter of metal, inches	Tensile strength, pounds	Safe capacity, tons
¾	5,700	½
⅞	9,000	¾
1	10,000	1
1⅛	16,700	1½
1¼	19,490	2
1⅜	21,000	2¼
1½	24,000	2½
1⅝	28,000	3
1¾	34,800	3½
1⅞	44,000	4½
2	47,000	5

diamond, round, or oval-shaped shells. Blocks should be ordered of heavy pattern and with self-lubricating bushings.

The sizes of wire-rope blocks are graded according to the outside diameter of the sheaves. It is well to use sheaves of as large

diameters as possible to avoid excessive bending of the rope. A large sheave, also, causes less internal friction in the rope and less breaking of the wires. Several sizes of sheaves may be used with any diameter of rope and, although small sheaves are to be avoided, blocks with overlarge sheaves are unnecessarily heavy. Table 17 gives sizes of blocks which are suitable for the diameters of ropes given.

TABLE 19.—SAFE CAPACITY OF ANCHOR SHACKLES
(Safety Factor-5 Based on Tests)

Diameter of metal, inches	Tensile strength, pounds	Safe capacity, tons
3/4	43,000	4
7/8	55,000	5 1/2
1	75,000	7 1/2
1 1/8	90,000	9
1 1/4	92,000	9 1/2
1 3/8	94,000	10
1 1/2	123,000	12
1 5/8	155,000	15
1 3/4	170,000	17
1 7/8	200,000	20
2	235,000	24

In a general way the strength of the body of any tackle block exceeds that of the rope which is reeved through it. The hook or shackle with which the block is fitted is invariably the weakest part of the block, and the supporting power of it usually determines the safe capacity of the block. A hook has a strong tendency to open out when subjected to a heavy load and, for this reason, blocks intended for heavy work should be fitted with shackles. For a given diameter of material, a shackle is approximately seven times as strong as a hook.

The following simple formulas give the safe lifting capacity of any hook or shackle of standard shape where the diameter of the metal is given. These formulas are useful in checking up the safe working capacity of any block at any time. The results obtained are stated in tons and have a safety factor of 5.

—For a hook, safe load in tons = $\overline{D}^2$, or diameter squared
—For a shackle, safe load in tons = $7\overline{D}^2$, or seven times diameter squared.

Where D = diameter of metal of hook in inches.

The values obtained by these formulas may be compared with those given in Tables 18 and 19.

It is evident that these formulas for computing the strength of hooks and shackles are very similar to those for manila and wire hoisting rope. In fact, the formula for the safe capacity of a hook is identical with that for a manila rope of the same diameter. The safe capacity of a 1-inch manila rope, for example, is about equal to that of a hook of the same diameter. The formula, also for the safe capacity of a shackle is identical with that for a cast-steel hoisting rope of the same diameter. The safe capacity of a 1-inch cast-steel hoisting rope is about equal to that of a standard shackle of the same diameter. This similarity between formulas aids in committing them to memory.

TABLE 20.—SUITABLE WORKING LOAD FOR A PAIR OF WIRE ROPE BLOCKS

	Singles, tons			Doubles, tons			Triples, tons		
Dia. sheave, inches	Regular pattern	Heavy pattern	Ex. heavy pattern	Regular pattern	Heavy pattern	Ex. heavy pattern	Regular pattern	Heavy pattern	Ex. heavy pattern
With Loose Hooks or Stiff Swivel Hooks									
6	1½	1½	2	2	2	2½	2½	2½	3½
8	2	2	2½	2½	2½	3½	3	3	4½
10	2½	2½	3½	3	3	4½	3½	3½	5
12	3	3	4½	4½	4½	5	5½	5½	6
14	4½	4½	5	5½	5½	6	6½	6½	8
16	6½	6½	6½	6½	6½	8	8	8	10
18	6½	6½	6½	6½	6½	8	8	8	10
With Shackles									
6	2	3	3	3	4	4	4	5	5
8	4	4	4	6	6	6	7	7	7
10	4	4	5	6	6	7	7	7	9
12	5	5	7	7	7	12	8	9	12
14	7	7	8	9	12	14	10	12	14
16	8	10	12	10	18	20	11	18	20
18	10	10	12	13	18	20	14	18	20

Computing Capacity of Blocks.—The capacity of any block can be ascertained by computations based on the strength of the pin and the steel straps supporting the sheaves. Blocks for wire rope are manufactured in several strengths. These are known as regular pattern, heavy pattern, and extra heavy pattern. Blocks for manila rope are also manufactured in several patterns. Ordinarily, the capacity of a block may be judged from the size of the hook or shackle but hooks and shackles may become separated from the blocks and it is then necessary to judge the capacity of the block from the size of the pin and straps supporting it. Each sheave is supported by the resistance of the pin to shearing in two places and the total load on the block is supported by the resistance of the total thickness of plates in bearing on the pin.

Table 21 has been prepared to aid in computing the strength of a block when the diameter of the pin and the thickness of the straps can be measured. The table has been computed for a safe shearing value of 10,000 pounds per square inch and a safe bearing value of 16,000 pounds per square inch.

TABLE 21.—DOUBLE SHEAR AND BEARING OF PINS

Diameter of pin, inches	Double shear, tons	Bearing of pin on a plate 1 inch thick, tons
3/8	1	3
1/2	2	4
5/8	3	5
3/4	4	6
7/8	6	7
1	8	8
1 1/8	10	9
1 1/4	12	10
1 3/8	15	11
1 1/2	18	12
1 5/8	21	13
1 3/4	24	14
1 7/8	28	15
2	31	16

The pin supports each block with its resistance to shearing in two places at each sheave; therefore only double shear is given in the table. To obtain the strength of a block from the shearing value of the pin, it is necessary only to multiply the value given for double shear by the number of sheaves. To obtain the strength of a block from the bearing value of the steel straps, the total thickness of all straps should be measured and the value of the straps in bearing on the pin will be in proportion to the bearing value of the pin on a plate 1 inch thick. If the block has been properly designed, its capacity computed from the strength of pin and from the strength of straps should agree approximately. If they do not agree, the smaller value should be accepted.

As an example, let it be supposed that a block with two sheaves has a pin ¾ inch in diameter and is supported by three straps having a total thickness of 1¼ inch. The capacity of the block in resistance to shearing may be taken from the table: $4 \times 2 = 8$ tons. Its capacity in resistance to bearing is $6 \times 1\frac{1}{4} = 7\frac{1}{2}$ tons.

WIRE-ROPE TACKLE

Wire-rope Tackle.—There is a considerable difference in the cost of wire hoisting rope and the cost of manila rope. The cost of the blocks for the steel rope is also greater. A manila-rope tackle has several commendable qualities, in that it can be operated by men pulling on the rope; the fall end can be readily tied and made fast. A manila rope also can be operated by passing the rope several turns around the winchhead of a hoisting engine or of a winch, the free end of the line being drawn off the winchhead as the latter revolves. This is called "surging." Three or four turns of a hemp rope will ordinarily give holding power sufficient to operate the tackle. This is impractical to do with a wire rope, as the metal of the winchhead is quickly eaten away by a few hundred feet of cable passing over it.

With a tackle employing steel hoisting rope, it is an impossibility practically for men to pull on the rope and operate the tackle. Where a wire hoisting rope is carried to a hoisting engine or to a winch, the end of the rope must be fastened securely to the drum of the machine. As the end of the rope is fastened to the drum, there is a limit to the length of rope which can be wound on it. The greater the diameter of the rope the less can

be wound on it. When there is more rope at hand than can be wound on the drum, the other end should be taken off the becket of the block and tied to some support over head, or the winch can be moved to a greater distance from the blocks.

In handling loads weighing over 2 tons, a tackle employing wire hoisting rope is preferable to one employing manila rope. Greater speed in hoisting can be obtained as less parts of rope are required to support the load. A particularly quick and efficient way of handling light loads is to utilize a tackle consisting of a single-sheave block with a single part of line running over it. This arrangement is known as a single whip. A steel hoisting rope ½ inch in diameter is particularly useful and convenient for a tackle of this sort. With a single whip, great rapidity of hoisting is secured, but no increase in lifting capacity is gained. The power can be supplied easily by a winch, and the rope, if necessary, can be quickly passed through several snatch blocks.

For heavy loads, hoisting rope ⅝ or ¾ inch in diameter should be made use of with either double or triple blocks. Wire hoisting rope ⅝ inch in diameter will be found a very useful all-around size. Some erecting companies will not permit the use of a steel hoisting rope which is less than ⅝ inch in diameter. There is a strong tendency among erectors toward overloading their tackle and, with a restriction placed upon the minimum size which may be used, a certain amount of risk is avoided. Blocks intended for handling heavy loads should be fitted with shackles instead of hooks.

Table 22 gives safe working capacities of wire hoisting rope tackles without any snatch blocks in lead line, but taking friction of tackle into account. Table 23 gives safe working capacities when allowance is made for power to overcome friction from tackle and from two snatch blocks in lead line.

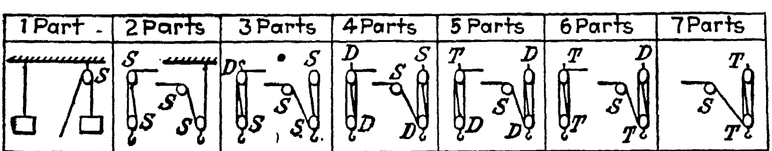
Loads of 10 tons and over can be best handled by two sets of tackle using ropes ⅝ inch in diameter or over. The two tackles should be attached to the load at two separate places by independent hitches.

A steel wire hoisting rope will not last foreover. If used continuously or if overloaded it will soon stretch and show other signs of deterioration. Excessive wear and depreciation in strength may be easily seen by the decrease in diameter and by the breakage of the individual wires forming the rope strands. To avoid rusting, wire rope should be kept well greased with a

TABLE 22.—SAFE LIFTING CAPACITY OF WIRE ROPE TACKLE

(Without Snatch Blocks in Lead Line—Blocks with Shackles and Extra Heavy Pattern—Plough Steel Rope)

Tons	10-inch blocks, ½-inch diameter rope	12-inch blocks, ⅝-inch diameter rope	14-inch blocks, ¾-inch diameter rope
1			
2			
3			
4	2 parts		
5	3 parts		
6	......	2 parts	
7	4 parts		
8	......	3 parts	2 parts
9	5 parts		
10	6 parts		
11	7 parts	4 parts	
12	......	......	3 parts
13	......	5 parts	
14			
15	......	6 parts	
16	......	......	4 parts
17	......	7 parts	
18			
19	......	......	5 parts
20	......	......	6 parts
23	......	......	6 parts
25	......	......	7 parts



To get number of parts add number of sheaves

heavy oil or a lubricating grease, particularly when coiled and not in daily use.

GIN POLE

Gin Pole.—The gin pole is a popular device much used for erection work. It is adapted to raising loads of medium weight to heights of 10 to 50 feet where a vertical lift only is required. It consists of an upright pole which is guyed at the top to insure a vertical position and is equipped with suitable hoisting tackle. Figure 290 is a diagram of a gin pole lifting a load. The pole is guyed by the four guys and is equipped with hoisting tackle and a

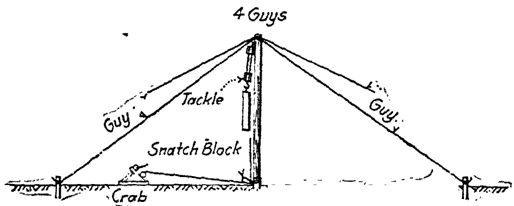


FIG. 290.—Gin pole.

snatch block near the foot of the pole. The fall or lead line of the tackle leads to the source of power which, in the diagram, is indicated as a hand-operated winch but might be a steam engine or any other power unit.

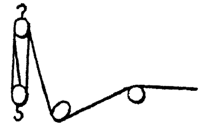
The pole itself may be a stick of natural growth or a square timber and should have a length and thickness suited to the work it is to perform. Gin poles which are longer than sixty times the thickness will ordinarily be too slender to use with safety except for the very lightest of loads, due to the flexibility of a long slender stick and its tendency to buckle when subjected to a compression strain. Table 24 gives strengths of spruce sticks for various cross-sections and lengths. The table is figured for long timbers used as gin poles with a proper allowance for the jars and jerks usually occasioned during the operation of hoisting. The values have been checked by observation of the actual behavior of gin poles used in erection.

The values given in the table are for straight spruce timbers free from any serious defects. A slight structural imperfection will often make a great difference in their supporting power. It is often the case that two poles of the same proportions, equally loaded, and similarly rigged, will act differently when a load is

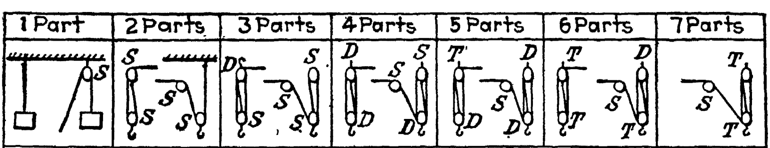
being hoisted. One pole, weakened possibly by slight twists or other defects in growth, will show signs of distress by buckling

TABLE 23.—SAFE LIFTING CAPACITY OF WIRE ROPE TACKLE

(With Two Snatch Blocks in Lead—Blocks with Shackles and Extra Heavy Pattern-Plough Steel Rope)



Tons	10-inch blocks, ½-inch diameter rope	12-inch blocks, ⅝-inch diameter rope	14-inch blocks, ¾-inch diameter rope
1			
2			
3	2 parts		
4			
5	3 parts	2 parts	
6	4 parts		
7	5 parts	3 parts	
8	7 parts	......	2 parts
9	......	4 parts	
10	......	5 parts	
11	......	6 parts	3 parts
12	......	7 parts	
13	......	......	4 parts
14			
15	......	......	5 parts
16			
17	......	......	6 parts
18	......	......	7 parts



To get number of parts add number of sheaves

slightly, while its companion pole will carry the same load without exhibiting any signs of having reached the limit of its strength.

TABLE 24.—SAFE CAPACITY OF SPRUCE TIMBERS USED AS GIN POLES

Section, inches	Length, feet	Safe capacity, tons
6 by 6	20	7
6 by 6	25	5
6 by 6	30	3
8 by 8	25	16
8 by 8	30	12
8 by 8	35	9
8 by 8	40	5
8 by 8	45	2
10 by 10	25	30
10 by 10	30	25
10 by 10	35	20
10 by 10	40	16
10 by 10	45	12
10 by 10	50	8
12 by 12	30	40
12 by 12	40	30
12 by 12	50	20
12 by 12	60	10

At times when a stick of suitable length is not at hand, there is a strong temptation to form a gin pole by splicing two shorter

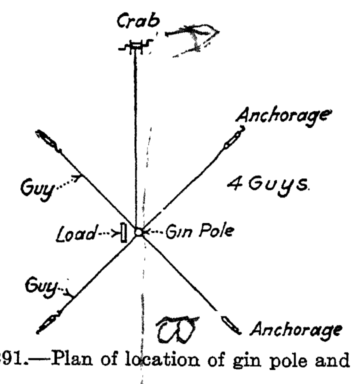


FIG. 291.—Plan of location of gin pole and winch.

timbers together. It is not advisable to use a pole formed by splicing in this manner, as very severe bending strains are occa-

sioned when a load is hoisted and such a makeshift has a strong tendency to break at the splice.

If it is necessary to use a spliced pole, the two sections should be butted one on top of the other and the joint should be covered by plank scabs either bolted or fastened by large spikes. To overcome the tendency of a spliced pole to buckle, an additional set of guys should be fastened at the splice. This will give the

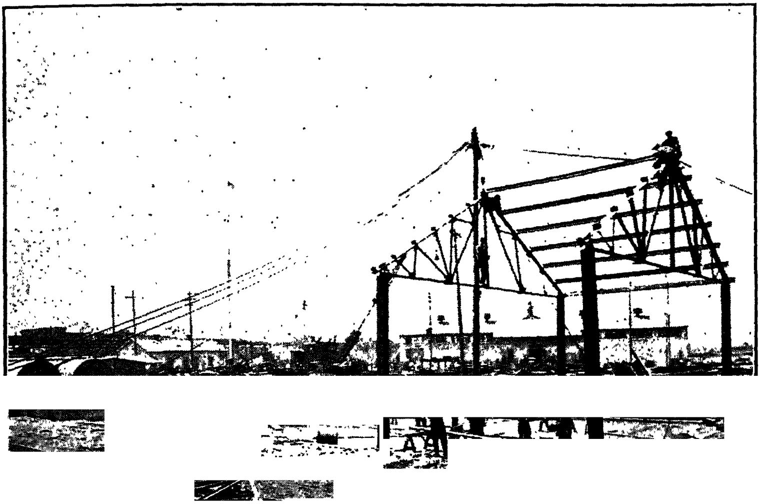


FIG. 292.—Erecting a roof truss.

completed gin pole two sets of guys, one at the top and one at the splice.

Guys.—There should be four guy lines secured to the top of the pole. The *guy ropes*, if of single rope, will usually be of larger diameter than the hoisting tackle rope and of sufficient length to reach the anchorages. The stress put upon a guy may vary from almost nothing, when the pole is strictly vertical, to about one-third of the load when the top of the pole is given a drift of one-fifth the height. When the top of the pole is given a drift of one-third the height, the stress upon a guy may become equal to one-half of the load. These stresses occur when the guys make an angle of 45 degrees with the ground. When the anchorages are placed further out the stress decreases somewhat, although the difference is not very large.

Frequently, the method of deciding upon the size of rope to employ for a guy is merely to select a larger rope for it than is used

for the hoisting line. It is safe practice to assume that the stress on any one guy is equal to one-third the weight to be lifted, and to choose a diameter of rope by the use of Table 10 which gives strengths of different sizes of rope. To illustrate: Let it be assumed that 3 tons are to be lifted. Three tons times one-third equals 1 ton, the stress to be taken by a guy. Table 10 shows 1 ton to be the safe load for a 1-inch diameter rope, which is a suitable size to use in this case. When a pole is to stand in a nearly vertical position, it will prove ample if the capacity of

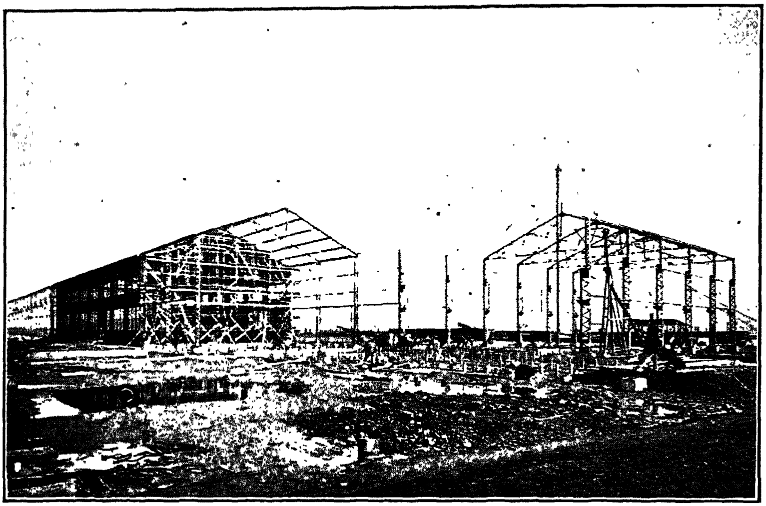


FIG. 293.—Erecting a steel mill building.

each guy is made equal to one-fourth the weight to be lifted. When it is not convenient to furnish rope of large size for the guys, a complete tackle rove with smaller rope may be employed instead, by attaching one block to the top of the pole and the other to the anchorage (Fig. 292).

While the guys to gin poles on light work are frequently single ropes, a better way of rigging a pole is to insert a small tackle in each guy. Each guy should consist of two parts, a length of light wire cable or stout rope about equal to the length of the pole and a light tackle (see Fig. 293, photograph). The tackle will usually consist of $\frac{3}{4}$-inch diameter rope rove through a double and a single 7-inch block. The tackle provides an easy and convenient method of adjusting the position of the top of the pole.

The lower or cable end of the guy should be secured to the anchorage. The upper or tackle end of the guy should connect the wire cable with the top of the pole. When the pole is to be used repeatedly, the upper ends of the guy tackles should be hooked into a piece of wire hoisting rope wound eight or nine times around the top of the pole; two turns for each guy.

The fall of each guy tackle should be brought down along the side of the pole and fastened to a cleat near the bottom of it (Fig. 294). A man standing on the ground at the bottom of the pole, by snubbing the line under the cleat and pulling up on it, can easily make adjustments in the position of the top of the pole. When the top of the pole has been pulled over in the position desired, the guys may be made fast to the tying cleats.

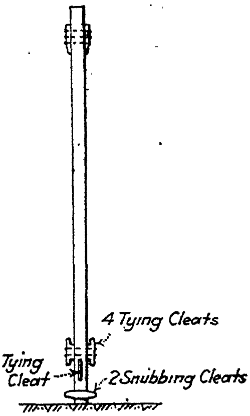


Fig. 294.—Gin pole with snubbing cleats.

The connection between the wire cable and the tackle block is usually made by means of a bowline-on-a-bight. To prevent the tackle from twisting, a pendant fashioned out of two or three pieces of wood, frequently called a "monkey tail," (Fig. 304) is inserted in the loop or between the ropes of the tackle. All hooks in guy tackles should be moused.

The *hoisting tackle* with which the gin pole is equipped should be of adequate size to raise the load with safety. The proper tackle may be selected by consulting Tables 13, 14, 22 and 23, giving the safe lifting capacities of tackle. For the ordinary run of light gin-pole work, a tackle formed of two 10-inch double blocks rove with 1-inch diameter rope will prove satisfactory.

Rigging Gin Pole.—It has been shown previously how to assemble a hoisting tackle. In *rigging a gin pole,* provision must be made for attaching the tackle to the top of the pole, as well as for attaching the guys and the snatch block. Figure 295 shows the top of a gin pole with the hoisting tackle secured to the top of the pole by a lashing and with the guy lines in place. The method shown is used by professional riggers for light work and is a desirable arrangement to employ. The operation is accomplished as follows:

The pole is laid flat upon the ground in a position from which it may be raised upright later. The first step is to form the lashing which will be engaged by the hook of the tackle block. Select a length of rope sufficient to make six or eight turns around the pole and with enough extra for a knot. The middle portion of this rope is then laid across the pole and one end is wound tightly

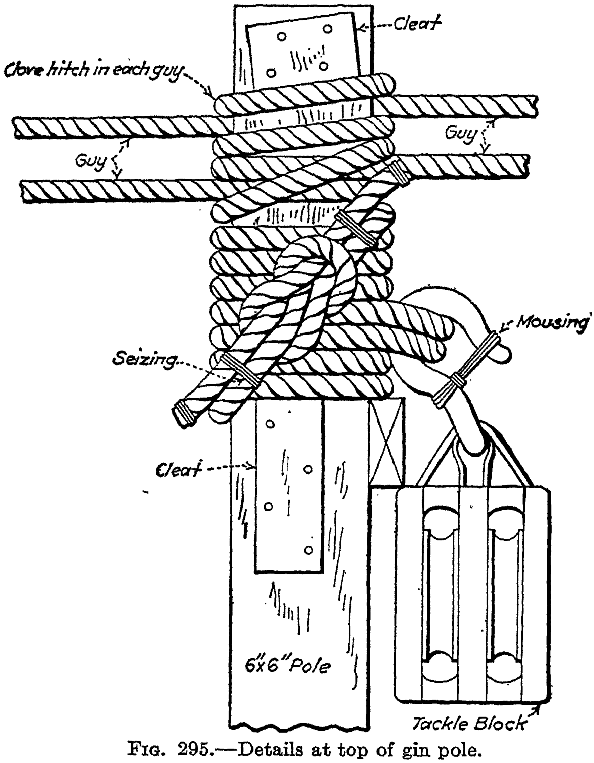


FIG. 295.—Details at top of gin pole.

around the pole three or four turns, each turn being laid snugly against the turn before; the other end of the rope is then carried around the pole in a similar manner but in the reverse direction. Both ends are then brought diagonally together across the lashing and tied with a square knot. The free ends of the rope are secured to the standing part by seizings, as shown in Fig. 295. The guy lines have still to be made fast to the top of the pole. A length of rope sufficient to make two guys is selected and at the middle of its length a clove hitch is formed which is then slipped over the end of the pole above the lashing, thus forming two

guys. The two additional guys are formed in like manner but with the hitch turned the other way. The lashing and the guys are made snug by wooden cleats nailed to the sides of the pole.

The hook of the tackle block is then inserted under the two middle turns of the lashing and a mousing is tied across the opening of the hook. A small piece of 2 by 4 should be spiked to the pole just below the hook to make the block hang clear of the

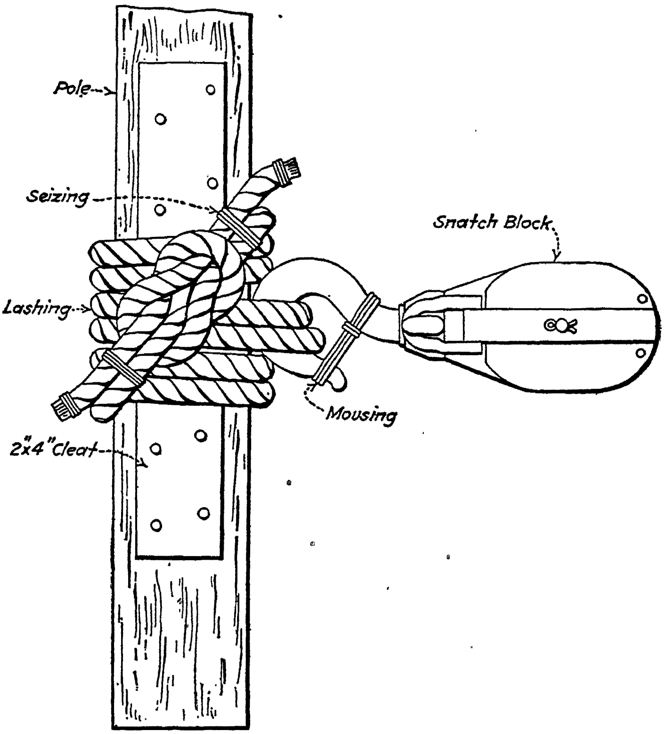


FIG. 296.—Foot of gin pole.

side of the pole. This will prevent the cheek of the block from being pressed against the pole by the load and split. The completed top of the pole should appear then as shown in Fig. 295.

The snatch block is attached to the pole close to the bottom with a lashing in the same manner as the tackle block at the top of the pole. This lashing should be held snug by cleats, the cleat toward the top of the pole being nailed securely to counteract any tendency of the lashing to move upward when hoisting.

The snatch block is hooked into the lashing on the same side of the pole as the hoisting tackle so that the hoisting line may run directly from the sheaves of the top block to the sheave of the snatch block. The hook of the snatch block is inserted into the lashing pointing downward and is tied with a mousing. The bottom of the pole when finished appears as shown in Fig. 296.

The bottom block of the hoisting tackle should now be pulled down near the bottom of the pole and tied fast so as to be accessible after the pole is raised.

The lashing which secures the blocks to a gin pole should be formed with rope which is strong enough to withstand the pull which will come upon it. Usually rope of the same size as the

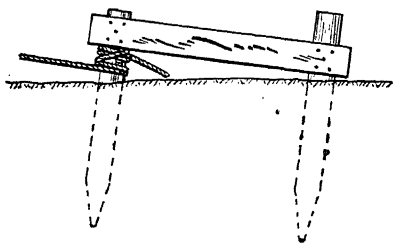


FIG. 297.—Guy anchorage.

guys may be used; care should be taken to engage as many parts of the rope as may be necessary to hold the load. Due to the cutting action of the hook on the rope, an allowance of 50 per cent increase over the actual load should be assumed in proportioning them.

Where the gin pole will be used repeatedly for hoisting as in the erection of roof trusses and similar work, it is better to attach the hoisting tackle to the pole with a lashing of wire hoisting rope instead of the manila rope shown in Fig. 295. The ends of the wire rope should be secured by wire-rope clips.

Provision for anchoring the guys must be made when suitable anchorages do not already exist. An anchorage, similar to that shown in Fig. 297, may be quickly constructed and is well suited for light gin pole work. It is made by driving two stout posts into the ground and spiking planks or 1-inch boards to them on each side as shown.

They may also be jointed by a lashing, as in Fig. 298. When the ground is firm and hard, stout iron bars driven into it will serve equally as well for light work. They may be lashed

together with soft wire. Anchorages for heavy work should be constructed as shown in Fig. 313.

Adequate provision should be made to hold the foot of the gin pole securely in position; particularly, it should be secured against

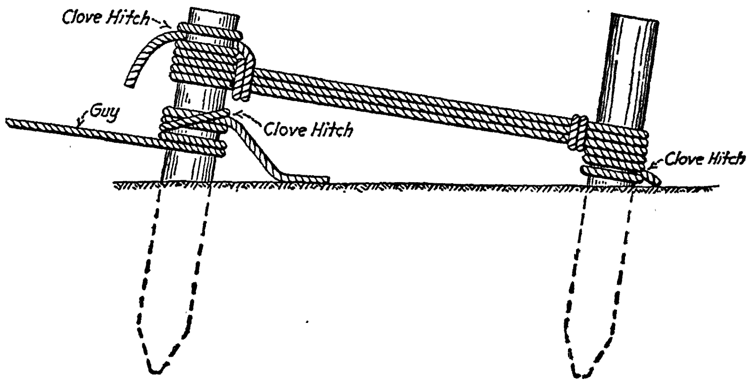


FIG. 298.—Guy anchorage.

the horizontal pull of the snatch block. A tackle may be used for holding against this pull, or the foot may be held immovable by a lashing or by a chain. Where it is necessary to give a drift to the top of a pole, it is well to embed the foot of the pole in the ground. Where the gin pole is to be moved frequently, as in

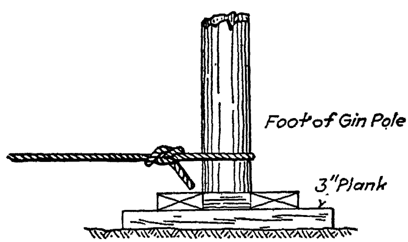


FIG. 299.—Shoe for foot of gin pole.

setting roof trusses, the foot should rest upon a sort of shoe made of plank upon which the pole may ride in moving from place to place (Fig. 299). The foot of the pole should be held in place in the shoe by cleats on all sides and the line attached to the foot of the pole for the purpose of moving it may be used to hold against the pull of the snatch block. The shoe shown in Fig. 300 is designed as a support for a large pole that is capable of raising heavy loads.

The *power employed* in gin-pole work is usually furnished by a winch, crab, or steam engine. The winch (Fig. 344) probably is used most frequently, being adapted to small operations such as erecting machinery, smoke stacks, and the like where only a few hoists have to be made or where the load is heavy and space for hoisting apparatus is limited.

The winch or crab may be placed in almost any location, and the fall can be led to it by passing it over one or more snatch blocks. These extra snatch blocks, however, introduce a loss of capacity due to friction and, for this reason, the crab should be placed, if possible, so as to receive the lead line direct from the snatch block at the foot of the pole. This restricts its best location to some part of the semicircle to the load side of the gin pole. The lead rope may pass directly under the load from the snatch block to the crab, but the crab will be in the most desirable location if the rope extends from the snatch block at right angles to an imaginary line connecting the center of the pole and center of the load, as the lead will then be clear of the load (see Fig. 291). With a sufficient number of snatch blocks, however, the lead rope may be led to the winch in almost any position.

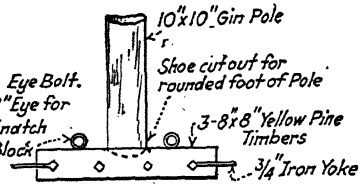


FIG. 300.—Shoe for gin pole.

A crab or winch can be stationed on the side opposite the load if a single block is attached at the top of the pole or a sheave is inserted in the top of the pole. The line will then run from the movable block up over the sheave at the top and then down the pole.

The winch may be anchored by driving stout iron bars or posts into the ground against which the cross-braces on the bottom of the winch may bear, or it may be lashed fast to some convenient object. Care should be taken to see that the lead rope is brought horizontally to the winch so as to pull downward slightly upon it. If the rope is allowed to pull upward on the drum, the front of the winch will rise off the ground and make hoisting almost impossible.

Erecting a Pole.—A small gin pole 30 or 40 feet long may be raised by hand. To do this the pole is placed in the angle between two of the guy anchorages (see Fig. 301). The foot is blocked or cleated so that it will have something to butt against

during the time it is being raised to an inclined position, and to prevent it from sliding laterally. When it is not convenient to block the end of a pole, it may be held from sliding by a kicker formed of several parts of rope. A man is then stationed at each anchorage. If the guys are not equipped with small tackle blocks, each rope should be snubbed with a round turn around the anchorage to give better control over the pull on the guy and permit adjustments in the length of it as the pole is raised.

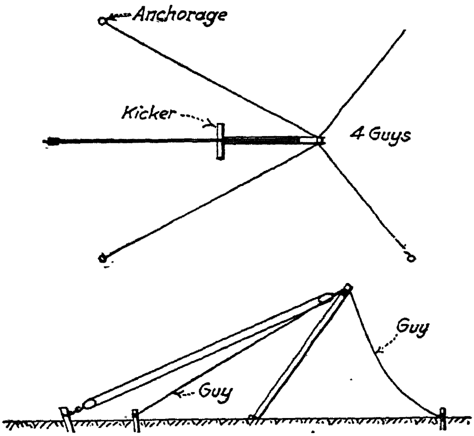


FIG. 301.—Raising a gin pole.

Several men are then sent to the top end of the pole which they raise above the ground as high as possible.

With the end of the pole held above their heads, the men walk toward the foot of the pole raising the end of it higher as they proceed toward the foot. In the meantime, men stationed at the guy anchorages toward which the pole is raised assist in the operation by pulling on those guys. The men at the other guy anchorages should keep the guy ropes at those points slightly taut adjusting them continuously as the pole is raised. When the pole is erected, the guys may be made fast, as shown in Fig. 297, by two round turns tied with a clove hitch.

A pole can be raised by hand power in the same way as indicated for raising with a winch in Fig. 303, by substituting man power for the pull of the winch. Where the guys are equipped with tackle blocks, the pole can be raised by these just as well as by the load blocks, if desired.

Where tackles are not inserted in the guys, it may not be possible to tighten the guy ropes by merely pulling on the rope itself. Greater power may be obtained by connecting a tackle temporarily to the rope and to the anchorage. The tackle

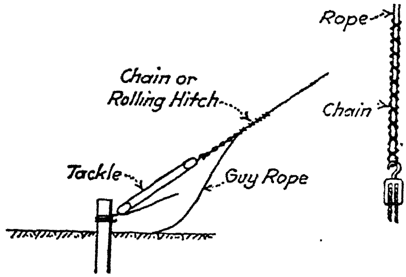


FIG. 302.—Tightening a guy by tackle fastened to guy with chain.

may be fastened to the rope with a stopper hitch (Fig. 275) or a chain (Fig. 302). In using a chain for this purpose, a short length of chain is laid across the guy rope at its middle and each half of the chain is carried around the rope in opposite directions, both parts of the chain crossing each other. Both ends are then

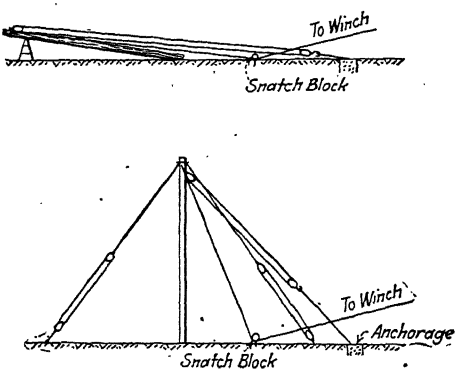


FIG. 303.—Raising gin pole.

brought together and the block is hooked into them. When a strain is put on the chain, it grips the rope securely.

Long, heavy gin poles require the aid of mechanical power to raise them and the crab or steam engine which is to be used to do the hoisting may be employed for erecting the pole. The operation, in a general way, is similar to raising the pole by man power. The pole, with guy lines and hoisting tackle secured to the top is placed in position on the ground. The top end of the pole

then is elevated and supported by a wooden horse or crossed timbers 3 to 5 feet above the ground, as shown in Fig. 303.

A small tackle of 7 or 8-inch blocks is provided for the free end of each guy. The connection to the anchorage may be made as shown in Fig. 304. A man is stationed at each guy anchorage to adjust the guy as the pole is raised.

The pole is raised by means of the hoisting tackle attached to the top of the mast, as indicated in Fig. 303. The fall end of the tackle rope is made to pass through a snatch block anchored in a suitable location and then to the drum of the crab or hoisting engine.

The pole is raised by pulling slowly on the fall. The pull on the rope should not be made continuous. After each pull, time

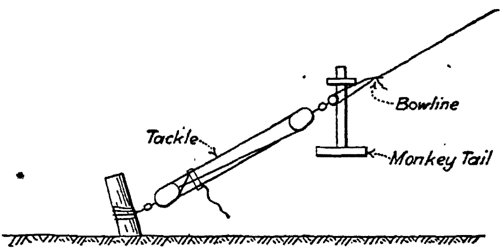


FIG. 304.—Guy anchorage.

should be given the men at the guy lines to adjust them and to allow the vibrations in the pole to diminish. With long, heavy poles, no effort is made to raise the pole by walking it up. The oblique pull on the top of the pole by the rope leading to the crab slowly up-ends it and brings it gradually to a vertical position. The tackles are allowed to remain as part of the guys and are useful later in making adjustments. In Fig. 292 (photograph) the tackle is seen to form the entire guy; in Fig. 293, it forms the greater part of it.

A heavy gin pole may be erected by a shorter and lighter pole in any case where it is impractical to raise the pole by either of the two ways just described. This is the best method to pursue when the gin pole is very long or has to be erected in constricted quarters.

Great care should be exercised in selecting a pole to make sure that the pole is long enough. If the stick is too short, it will be impossible to raise the load the full distance. Strange to say, this mistake is often made by erectors and the pole after having

been erected is found to be several feet too short. In computing the length of pole required, the position of the sling on the object to be raised must be taken into account as well as the height of the final position of the object raised above the foot of the pole. Space must also be provided for the blocks and hooks. The load should be grasped just a little above its center of gravity. A minimum distance of at least 5 feet, and preferably 7 feet, should be allowed for the hoisting tackle, the slings, and the small section of pole above the guys. If the pole is to be moved along as in erecting roof trusses, any unevenness in the ground should be allowed for.

Location of Winch.—The raising of a light load may be accomplished by a gin pole equipped with a winch bolted to the lower

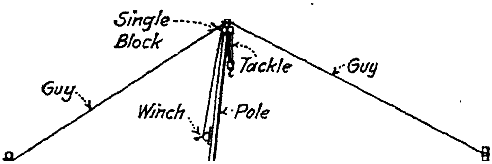


FIG. 305.—Gin pole with winch.

portion of the pole or by means of a crab located on the ground at a distance from the pole.

When the pole is to be operated by a winch bolted to the pole, it is necessary to place the winch on the back of the pole on the side opposite to the tackle sustaining the load so that the men operating it will not have to stand under the load. Also, as the pole is usually given a certain amount of drift at the top, the winch should be on the upper side (see Fig. 305).

With the tackle on one side of the pole and the winch on the other side, difficulty will be experienced in leading the rope from the tackle to the drum of the winch, unless a sheave is inserted in the pole so that the rope may pass through it. This difficulty may be avoided somewhat by allowing the winch to project to one side of the pole and arranging the tackle so that the rope, after going around the bottom block, will pass over a single block at the top of the pole on one side and thence downward along the pole to the drum of the winch, as shown in Fig. 305. With wire rope of small diameter and a comparatively light load, the usual arrangement of blocks may be retained and the rope may be allowed to drag against the side of the pole.

When the power is furnished by a crab located at some distance from the pole the arrangement of blocks usually seen in a hoisting tackle may be employed, as shown in Fig. 290, with the fall passing from the top block to a snatch block near the ground.

The engine or the winch should preferably be kept 25 feet or more from the pole or nearest snatch block. If the fall has a short lead to the drum, it will pile up in one place on the drum, and the hoisting will be accompanied by sharp jerks in the tackle. If the lead to the drum is a long one, the rope will travel smoothly

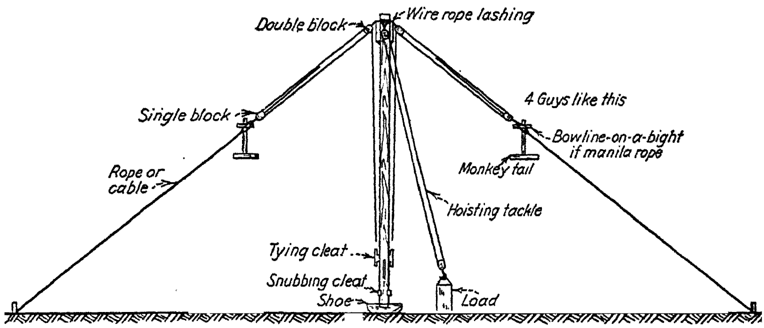


FIG. 306.—Typical gin pole.

back and forth from one end of the drum to the other, making an easy angle with the snatch block. The rope will then wind smoothly on the drum in orderly fashion, each turn taking its position against the one wound on the drum before.

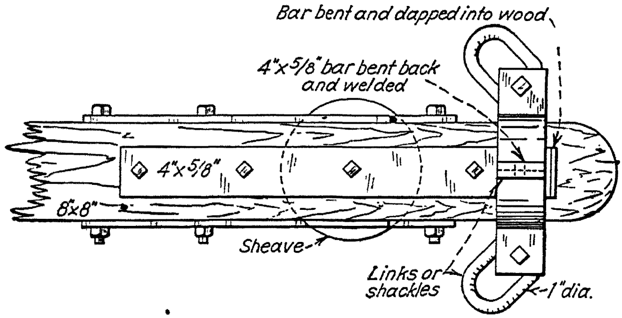
REFINEMENTS IN GIN POLE RIGGING

The methods used in rigging a gin pole can be modified in several ways. The pole illustrated in Fig. 306 represents possibly the best manner of rigging. The pole in its main features is made as shown in Fig. 294. The top is made with two cleats bolted to the pole. They support the lashings for the hoisting tackle and guys.

If there is enough gin pole work to be done, the pole can be arranged so that it can be revolved by equipping it with suitable irons similar to those shown in Fig. 307. The guy band is made in two parts with provision for four guys. It is loose around the hole, the side plate under it being bent and dapped into the wood of the pole. A pole equipped with a top like that shown and

rigged in other details to conform with the figure will be found to be a very flexible and useful unit.

It is always desirable to hoist as quickly as possible, and when the load to be lifted is light, a two-part tackle will often be suffi-



Corners of 8x8 champfered under loose guy band

Fig. 307.—Top for revolvable pole.

ciently strong and will permit rapid hoisting to be done. Two single blocks are needed, one of which is lashed to the top of the pole. One end of the rope is secured around the top of the pole

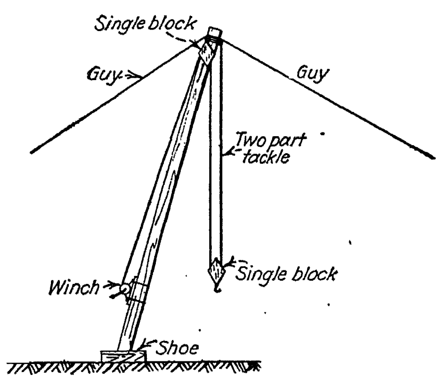


Fig. 308.—Two parts for fast hoisting.

instead of being attached to a becket of one of the blocks (see Fig. 308).

ACTUAL GIN POLE WORK

Erection of a Smoke Stack.—The stack should be placed on skids and rolled into a convenient position near the base of the gin pole. If possible the stack should be brought into position

on the ground so as to lie within the angle formed by the two guys on the load side of the pole. In this position, the lower block of the hoisting tackle can move straight upward and there will be less chance of the stack interfering with any of the guy ropes.

The sling for raising it should be located just above the middle point of the stack. If manila rope is used for a lashing, it should be passed about six times around the stack. If a wire-rope sling is used, pieces of ⅞-inch board should be inserted between the sling and side of the stack to prevent the sling from slipping, or the sling may be located so as to bear against a row of rivets.

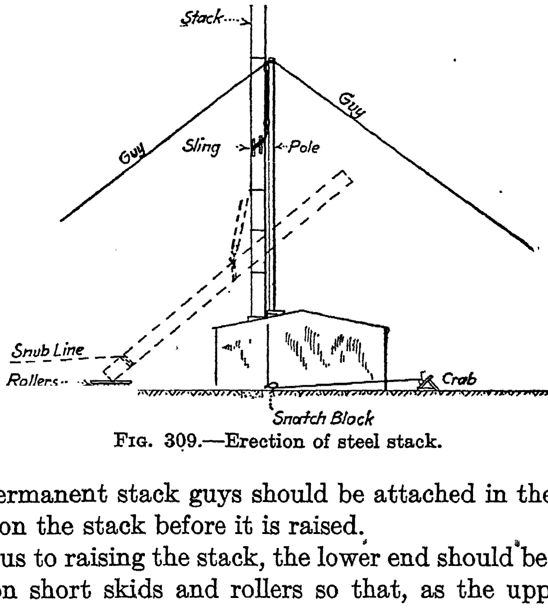


FIG. 309.—Erection of steel stack.

The permanent stack guys should be attached in their proper position on the stack before it is raised.

Previous to raising the stack, the lower end should be arranged to rest on short skids and rollers so that, as the upper end is raised, the bottom end, still resting upon the rollers, may roll forward and adjust itself to the general position of the stack. A snubbing line should be attached to the lower end to prevent its rolling forward too rapidly and to keep a constant control over its movement during erection. The snubbing line may best contain a pair of blocks to give ample controlling power.

The stack, when well up in the air, may interfere with one of the guy ropes. As this interference will usually occur on the load side of the pole, a slight adjustment in the position of the guy will be sufficient. A small tackle secured to the guy rope by a stopper hitch or a small chain may be used to bring the guy

to a new anchorage if necessary, while the old anchorage is being abandoned. If necessary, a new guy may be fastened to the top of the pole and the old guy may be removed. The easiest way, if possible, is to move the end of the stack, that is on rollers, around into a position which will throw the upper end clear.

As the stack is elevated, the rollers will continue to support part of the weight until the stack is lifted clear of the ground. The pole will then have to take the full weight of the load. The power required for raising a stack is best supplied by a winch located on the ground at a convenient distance from the base. It will usually be found that a winch will do better work when placed at some distance from the pole rather than near it.

The usual steel stack is designed with its base resting on supports well above the ground; frequently the base is placed on the boiler-house roof. In such cases, it will usually be necessary to erect the pole on the roof also and to provide a shoring of heavy timbers to support it.

Erection of Bulky Machines.—If an object of large bulk were to be erected by a single gin pole, it would be necessary to employ

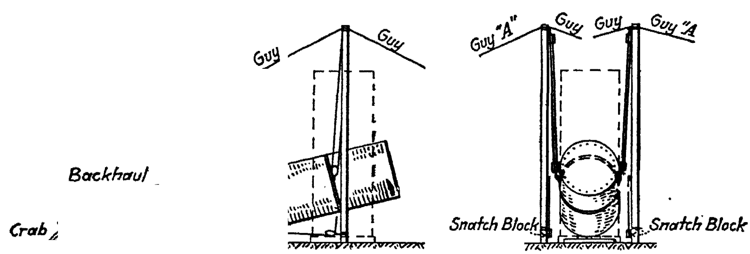


FIG. 310.—Erection of a bulky object.

a very long pole so as to be able to gain sufficient drift to prevent the load from coming in contact with the side of the pole. If the object to be erected is very bulky, it will usually prove impractical to use a pole with sufficient length to gain the necessary drift. In such cases two gin poles may be used, one on either side of the load. With two poles there will be two complete hoisting rigs. There will be two poles, two tackles, two snatch blocks, two crabs or winches, and twice as many guys and other gear. Figure 310 shows an arrangement of rigging for setting a large, heavy, steel shell. The arrangement is typical of the methods usually employed for erecting objects of large bulk.

The gin poles should be located on either side of the foundation upon which the machine is to be set. They should be located so as to provide a space of about 1½ feet clear from the side of the machine so that sufficient space is left in which the lower block may travel. It is very important to tighten the guys marked *A* in the illustration so that it will be impossible for the poles to be pulled inward toward each other by the load, thereby decreasing the space and making the hoisting difficult. Both the crabs which are to furnish the power are preferably located in the same general vicinity so that the hoisting operation may be more easily supervised. As may be seen by an inspection of Fig. 310, it is necessary to reeve the two hoisting tackles in opposite directions, one being reeved in what might be called a right-hand and the other in a left-hand direction.

The arrangement of the pair of gin poles shown in Fig. 310 may be modified somewhat, as shown in Fig. 311. The arrangement shown in Fig. 311 is somewhat simpler as two guy lines are replaced by the two planks connecting the tops of the poles. The planks prevent the poles from being pulled together by the load and in this way they replace the guys to good advantage. The planks are preferably bolted to the poles but four or five heavy spikes will usually prove sufficient fastening. With the arrangement shown in Fig. 311, the poles must extend above the top of the load. The rigging may be further simplified by using two chain blocks to do the hoisting. The blocks will then replace the hoisting tackle, the snatch blocks, and the two crabs. Extra-long chains, however, will be needed on the chain blocks in most cases on account of the vertical distance of the lift.

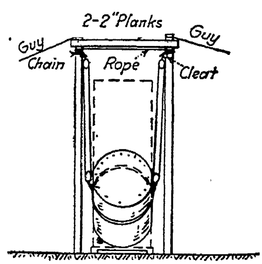


FIG. 311.—Erection of bulky object, modified rigging.

The cleats at the top of the poles over which the small chains or wire-rope slings are hung supporting the tackles, serve principally to suspend the tackle a sufficient distance from the pole to prevent the cheeks of the block from becoming split by being pressed against the poles. The cleats may be made of 2- or 3-inch material and may be spiked fast or dapped into the side of the poles about 1 inch. It is important to prevent the cheeks of the blocks from splitting as a split cheek will often permit the rope to run off the sheave and to jam between the sheave and the side

strap. In such a position, it will be almost immediately cut in two.

If the object to be erected is assumed to be a large steel shell weighing 3 or 4 tons the usual procedure would be to roll it to the vicinity of the foundation on skids and rollers and, when there, to tie it securely with lashings and ropes to provide fastenings for the tackles.

The main lashing by which the shell is to be lifted is placed around it just above the center of gravity. Six or eight turns of rope are necessary. Into this lashing the hooks of the lower blocks of the hoisting tackle are fastened. The opening of each hook is then closed by a mousing. If the hooks of the blocks were merely loosely hooked into the lashing, they would slip and be pulled circumferentially to the top of the shell when the strain is put on the falls. To prevent them from slipping in this manner, they should be held in position by a rope passed entirely around the shell.

When all preparations have been made to lift the machine, it should be moved forward between the two poles so that the lashing is well within reach of the hoisting tackles. The easiest way to move it into position is by a tackle fastened to the front end and operated from one of the crabs. A backhaul tackle should be secured to the rear end of the shell to prevent it rolling ahead too rapidly or otherwise getting out of control.

It should be arranged so that the rear end of the shell will ride on rollers as the forward end is raised off the ground. As the forward end is lifted, the rear end then rolls forward. In this position, the tackles are carrying between two-thirds and one-half of the load depending upon the position of the lashing; the remainder of the weight is taken by the rollers under the rear end. Eventually the shell must be lifted clear of the ground and the full load is then supported by the two poles. The shell should be set temporarily on short lengths of $\frac{3}{4}$-inch diameter pipe laid radially on the foundation or on steel wedges. The pipes and wedges will allow the machine to be turned easily in any direction and the wedges will permit vertical adjustments of position to be made.

SHEARS

Shears.—The shears is a popular device frequently employed in the erection of heavy machinery and other bulky objects. It is

formed (see Fig. 312) by two poles or sticks crossed at the top with the hoisting tackle suspended from their intersection. The shears has the following advantages: it possesses pronounced lateral stability; it requires only two guys, one fore and one aft; it is adapted to working at an inclination from the vertical and, in its simpler forms, it is quickly assembled and erected.

The legs of the shears may be sticks of natural growth, rounded poles, squared timbers, or heavy planks, according to the circumstances in each case. No set rule has been evolved for finely proportioning the size of the legs according to the loads they are to bear. In a general way, it may be said that a shears, the legs of which are only forty times their least thickness will be of a very sturdy construction and adapted to heavy loads. Where the length of the legs is sixty times their thickness, the shears is suitable for handling only very light loads. This last proportion is about the limit for hoisting purposes, as the shear legs, due to their inclined position and to the fact that the bottoms of the legs frequently do not have an even bearing, are rendered particularly liable to buckling strains. Table 24, giving strengths of square spruce sticks when under compression, may be used as a guide for selecting sizes; ample allowance should be made for the legs being in an inclined position and having an uneven bearing.

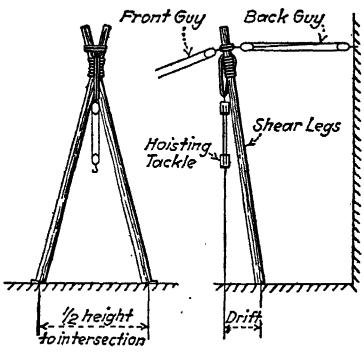


FIG. 312.—Shears.

The *hoisting tackle* may be chosen from Table 14. The same general principles apply in selecting a hoisting tackle for a shears as for a gin pole. It should be remembered in this connection, however, that a shears is usually erected for very heavy work and the tackle required will be of larger size than ordinarily would be used on a gin pole. A chain block is frequently used with a shears in place of tackle blocks where the height of the lift is not too great. The use of a chain block is advisable wherever possible in that it does away with the necessity for a winch and snatch blocks.

The *guys* for a shears may be proportioned in the same manner as the guys for the gin pole, but the back guy is a very important

part of the shears rigging as it is under a considerable strain constantly while hoisting. It should be designed to take a strain equal to one-half the load to be lifted. The front or lazy guy does not have much strain thrown upon it and is mainly used to aid in adjusting the drift and to steady the top of the shears when hoisting or placing the load.

One of the main advantages of a shears, outside of its lateral stability, is the easy adjustment of drift which may be obtained by its use (see Fig. 312). This characteristic may be utilized to advantage where it is desirable to pick up a load with the shears in a nearly vertical position and deposit it farther forward. This may be accomplished easily by slacking of the rear guy and tightening on the front guy. The length of drift which may be secured with a shears in this manner, and the space existing between the two inclined legs are characteristics which adapt it to the erection of large machines.

A tackle is desirable in both the forward and the rear guys to permit adjustments to be made in the drift. The tackle may be inserted at the anchorage end of the guys; or for heavy work, a tackle may be used for the entire guy (Fig. 312). If there is nothing in the locality to which the guys may be fastened, anchorages must be provided for them. Posts driven into the ground similar to those used in gin-pole work may be used for this purpose when the load to be lifted is light, but for heavy work a "deadman" should be installed.

The deadman (see Fig. 313) may be constructed by embedding a timber 6 or 8 feet long into the ground with a chain or wire-rope sling attached. The sling should be long enough to reach above the surface of the ground and provide a fastening for the guy. To give a greater purchase in the ground, a number of thick planks should always be placed in front of the timber, as shown in the figure.

Figure 312 represents a shears with front and back guys. The spread of the legs, as shown in Fig. 312, should be equal to about one-half of the height. The maximum drift allowable is usually assumed as equal to about forty-five degrees. A shears may be formed by lashing the two legs together with ropes or by fastening them together with a bolt. A shears for handling very light loads, such as pipes and the like, may be formed in a few minutes by fastening two timbers or planks together by a bolt through their intersection (Fig. 314). A shears made by lashing its legs

together with ropes is particularly well adapted for lifting heavy loads, but considerable time is required for the various operations necessary to rig it completely.

A shears is constructed with a rope lashing in the following manner (see Figs. 315, 316 and 317).

The two sticks which are to form the legs of the shears are placed flat upon the ground with the butts or bottoms of the poles spread apart a distance equal to about one half of the height of the shears. The tops of the sticks are crossed and should be elevated 2 or 3 feet above the ground so that they may be conveniently lashed together.

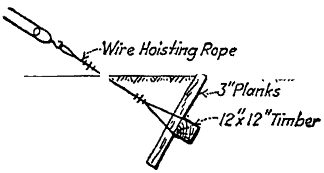


FIG. 313.—Deadman.

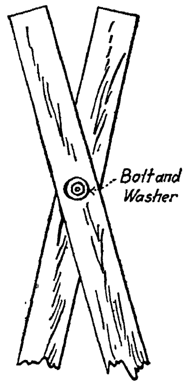


FIG. 314.—Shears bolted.

A length of rope, about ¾ inch in diameter is then selected which will be long enough to make about 30 or 40 turns around the tops of both legs (Fig. 315). The middle portion of this length of rope is then laid crosswise of the sticks at their intersection and one end of the rope is taken around the sticks 8 or 10 turns, working away from the center of the lashing, each turn being laid snugly against the preceding turn and pulled tight, as shown in Fig. 315. Then, working back toward the center of the lashing,

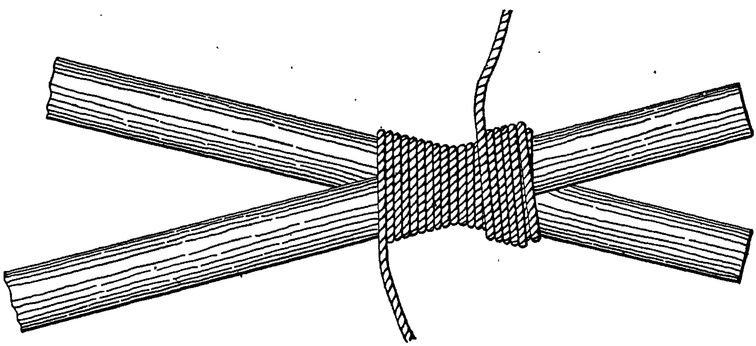


FIG. 315.—Lashing of shears' legs.

the rope is taken around the sticks, thus forming a lashing two layers thick. The other end of the rope is carried around the sticks in a like manner but in the reverse direction. This having been accomplished, both ends of the rope are carried back to the

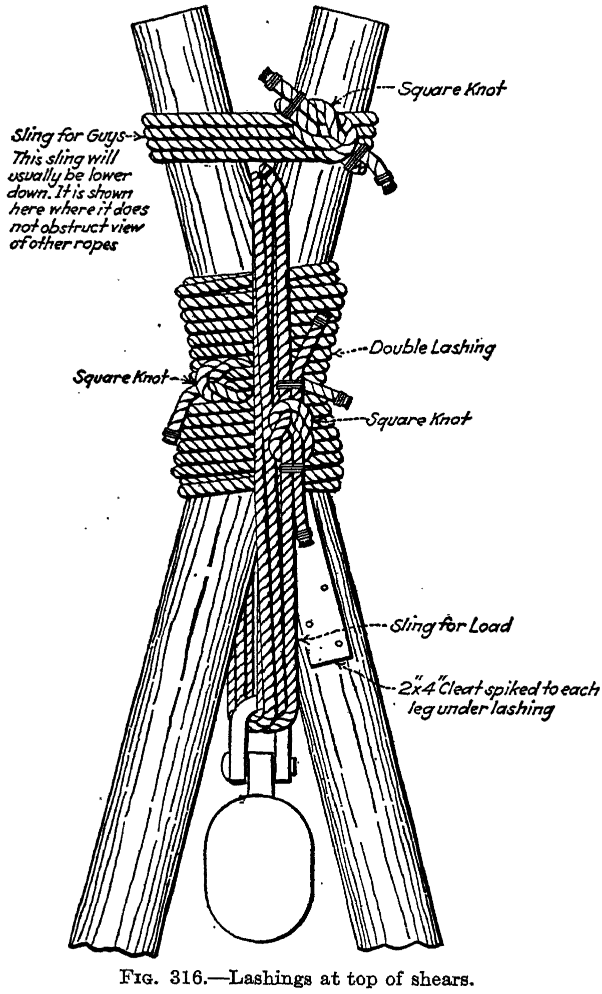


FIG. 316.—Lashings at top of shears.

center of the lashing where they are tied together with a square knot. The lashing should appear then as shown in Fig. 316. A small bar should be used to pull each turn of the lashing tight. The bar should be inserted in a marlinespike hitch (see Fig. 280)

formed in each turn of the lashing, each turn being pulled as tight as possible before the next turn is taken around the sticks. When the lashing has been completed, a 2-by-4 cleat should be nailed against the underside of it on each leg of the shears (Figs. 316 and 317).

The *sling* for the hoisting tackle must now be placed. Several turns of stout rope, sufficient to carry the load, are carried around the lashing just placed and between the sticks, as shown in Fig. 316, leaving plenty of slack to be engaged by the shackle or the hook of the hoisting tackle. The sling is completed by tying both ends of the rope together with a square knot.

To provide a *fastening* for the *guys*, a sling is made by winding four or five turns of stout rope about both sticks above the lashing in the manner shown in Fig. 316, finishing by taking a turn around one stick and tying the ends of the rope in a square knot.

The hoisting tackle is now hooked into the sling, the opening of the hook, if there is any, being closed with a mousing. The bottom block is pulled down and lashed to one of the legs of the shears so as to be accessible when the shears is erected. The guys are made fast to the sling provided for them and also to their anchorages. The shears is now ready to erect. This may be accomplished in the same manner as when raising a gin pole.

The shears having been raised to an upright position, it is necessary to make some provision for holding the legs from lateral displacement. The legs should always be held from spreading by connecting them with a lashing, as shown in Fig. 317. To hold the legs against sliding in other directions, such measures should be employed as may be dictated by the existing conditions.

A snatch block is necessary at the foot of the shears to take the lead line running to the crab or other hoist. The position of this snatch block will vary with the position of the crab. It may be conveniently chained or lashed to the bottom of one of the legs, or a separate anchorage independent of the shears may be provided for it.

The shears is often a useful means for raising light loads such as pipe or small machine parts. In such cases, great strength or lifting capacity is not required and a shears may be quickly and easily improvised from two planks or light poles by bolting them together where they cross (Fig. 314). The intersection may be reinforced by a small lashing and a sling for the hoisting

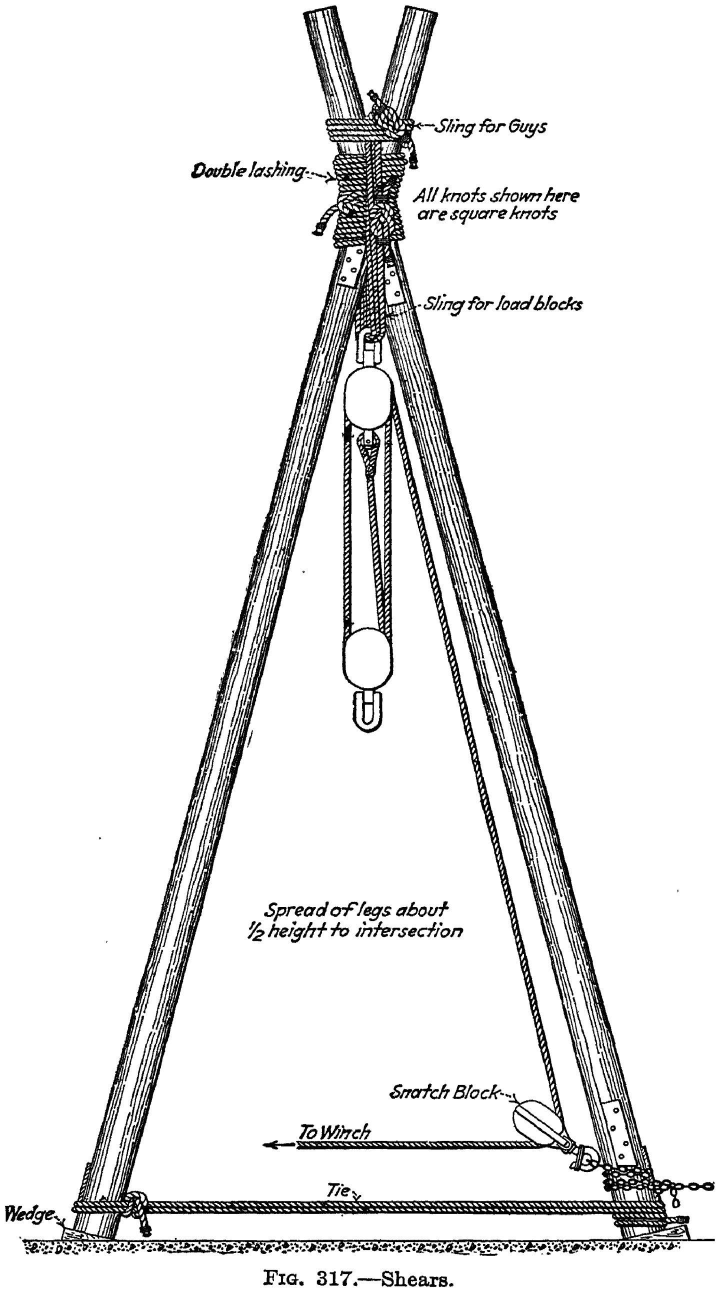


FIG. 317.—Shears.

tackle may be placed around the intersection of the legs, or the tackle may be suspended from a sling or chain thrown over the crotch in any way that is convenient.

For light work of this character, tackle blocks in the guys are unnecessary and the guy ropes may be secured to a stout post or similar object, taking one or two turns of rope around it so that the length of the guys may be easily adjusted.

POLE DERRICK

The *pole derrick* (Fig. 318) frequently called a "dutchman" is essentially a gin pole constructed with a sill and with knee-braces at the bottom. It is frequently equipped with a sheave

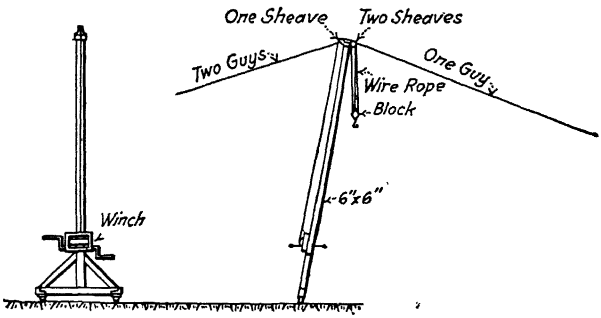


FIG. 318.—Pole derrick.

inserted in the upper portion of the mast. The sill and braces give the derrick stability in two directions so that only one front guy and one rear guy are necessary. Three guys, however, are often used, the additional guy being added in the rear. The two rear guys give a better chance to pick anchorages and in that way, facilitate moving it from place to place.

The pole derrick may be used to good advantage where a gin pole might also be used, especially where the pole would require frequent moving about as in setting the girders and beams in wooden mill-constructed buildings. As the chief advantage of a pole derrick lies in the facility with which it may be shifted from place to place, it is not practical for extreme heights of poles, since it is heavy and hard to handle in the larger sizes. It is particularly adapted to light erection work such as setting the steel work in small steel buildings, setting light trusses, purlins, and the like not too high above the ground.

The pole derrick exists in various types and modifications. One type may be purchased from supply companies which is permanently equipped with iron fittings and includes a sheave in the pole, a winch, and iron wheels let into the sill upon which the derrick may be rolled sidewise; other types which may be fashioned on the work appear in various forms. Usually a small winch is bolted to the mast and the derrick is moved by sliding it upon planks.

The improvised pole derrick, shown in Fig. 319, is a very simple apparatus but it is effective enough for many purposes. The hoisting tackle is suspended from a sling attached above the

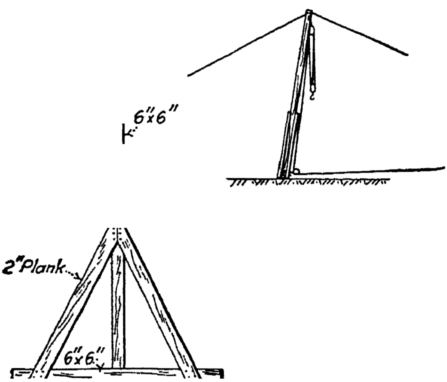


FIG. 319.—Dutchman.

cross-piece, or the top block may be hooked into a lashing in the same way as at the top of a gin pole. The two guys may be fastened by clove hitches but usually consist of tackles hooked into two or three turns of rope wound around the pole.

The pole derrick, shown in Fig. 320, is slightly further developed as it is equipped with a winch clamped to the back of the mast. A sheave is inserted in the mast near the top to guide the hoist fall from the tackle, which is in front of the mast, to the winch which is fastened to the back of it. This sheave is often omitted, the winch being moved slightly to one side, the rope being led from the top block to the winch and allowed to drag against the side of the mast. While this method of rigging is not to be recommended, it may be used for light work particularly where wire rope is used in the hoisting tackle.

Care must be exercised in constructing the derrick to fix the height of the winch above the sill, so that it may be operated easily, and also to arrange the braces, so that they will not interfere with turning the crank of the winch. To avoid this interference, the braces may be placed well below or above the wnich, or one brace may be omitted and the remaining brace run high up on the mast and bolted securely.

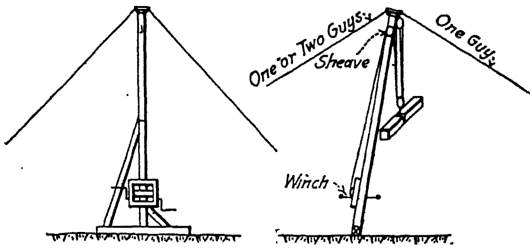


FIG. 320.—Dutchman.

The Monkey.—When fairly heavy loads are to be lifted and a steam engine or crab is to be used for furnishing the power, the

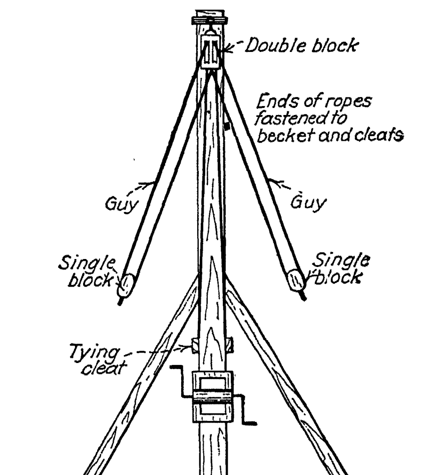


FIG. 321.—Dutchman with adjustable guys.

ordinary type of pole derrick or dutchman is too light to withstand the pull of a snatch block and a device with more stability is desirable. These requirements have led to the development of a

modification of the pole derrick which for want of a better name is often called a "monkey."

The construction of the monkey is shown in detail in Fig. 322. As may be seen by an inspection of the illustration, the device consists in the main of a mast or pole which is braced against overturning in three directions. The mast is frequently given a slight tilt forward to allow it to be used in erecting an object and at the same time not interfere at the sill. The braces running from the top of the mast to the sills may be formed of 2-inch

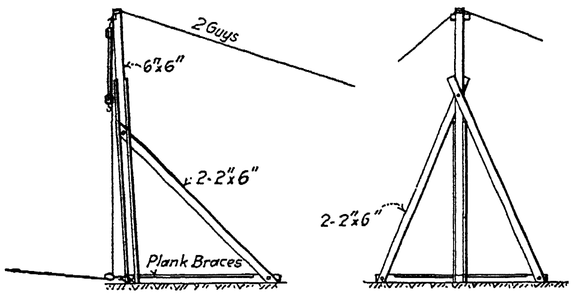


FIG. 322.—Monkey.

plank and are preferably bolted if the monkey is to be used frequently. Two additional plank braces should be spiked to the sills so as to brace them horizontally.

The snatch block may be secured to the foot of the pole by a small chain or a rope lashing. It will usually be necessary to anchor the monkey to prevent it from being moved horizontally by the pull on this block. Two back guys are usually employed when listing heavy loads, though objects of small weight may be erected without them.

The monkey is largely used in the erection of columns in structural-steel work for which it seems particularly well adapted. It is shown in use for this work in Fig. 293 (photograph), and in the erection of a timber girder in Fig. 152.

DERRICKS

Rigging.—The *stiff-leg* and the *guy derricks* are identical with respect to rigging; the chief difference in the two derricks is in the method used to hold the mast in a vertical position. Each type is equipped with a hoisting tackle suspended from the end of the boom to handle the load and with a tackle connecting the boom and the mast for the purpose of raising or lowering the

boom. Both types of derricks, also, may be equipped with a bull wheel attached to the mast by which the mast with the boom attached may be revolved. In the manner of rigging and in the tackles, both derricks are identical in these particulars. Either type of derrick may be operated by hand power, by a steam engine, or by any other power unit.

Figures 323 and 324 show, respectively, a hand-operated guy derrick and the same variety of stiff-leg derrick. Figures 325

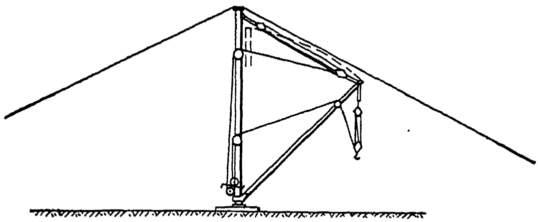


FIG. 323.—Hand-operated guy derrick.

and 326 show a guy and a stiff-leg derrick intended to be operated by a steam or other hoist. In all four figures, it will be noticed that the hoisting tackle is rigged in the same manner. It is suspended from suitable irons attached to the end of the boom, the upper block being connected to it by means of a shackle.

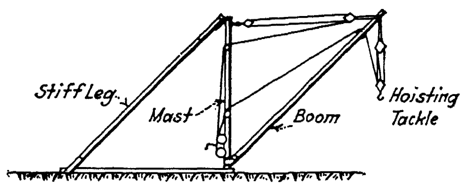


FIG. 324.—Hand-operated stiff-leg derrick.

The lower block is usually fitted either with a hook or, when on derricks of large lifting capacity, with a lashing shackle. The hoisting line, in all cases, runs from the lower block upward to a sheave inserted in the boom so as to pass through to the upper side of the boom.

The boom is raised and lowered by a tackle connecting the top of the mast and the end of the boom. The tackle is attached to the mast and boom iron by suitable links and shackles. The boom line is carried from the movable block, connected to the boom, back to the mast in all cases. Thus far the derricks are similarly equipped. If the derricks are to be operated by a winch

on the back of the mast, both hoist and boom lines must be led through the mast by passing over sheaves inserted in it. From these sheaves, the lines pass down the back of the mast to the winch, as shown in Figs. 323 and 324.

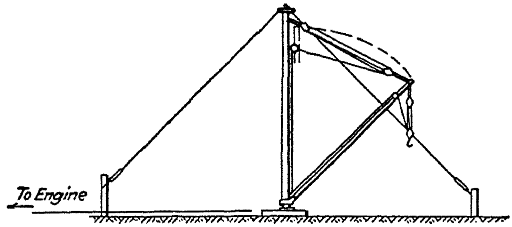


FIG. 325.—Engine-operated guy derrick.

If the derricks are intended to be operated by some form of hoisting engine, both hoist and boom lines are led so as to pass through the center of the casting at the foot of the mast. The usual method of accomplishing this is shown in Figs. 325 and 326. As shown, the hoist line passes from the sheave in the end of the boom along the upper side of the boom to the casting at the foot of the mast. The boom line runs from the block attached to the

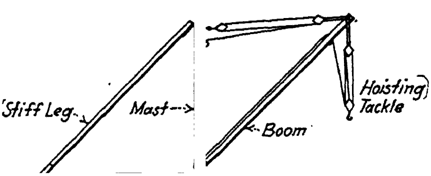


FIG. 326.—Engine-operated stiff-leg derrick.

boom to a sheave attached to the front of the mast, passing downward along the front of the mast to the casting at the foot. Both hoist and boom lines after passing through the casting are led over twin sheaves attached to the foot casting and from them to the drums of the hoisting engine.

Derrick booms may be swung by hand using a tag line tied to the boom end or turned by a lever inserted into suitable irons at the back of the mast. Swinging the boom by hand is suitable for work in which the boom is only swung occasionally or that in which the boom will be swung through a small arc of a circle and will require careful maneuvering. Such a condition exists in erecting structural steel for buildings which are several stories

high and where the guys anchored close in to the derrick must be avoided in swinging the boom.

The derrick boom may be swung by a steam engine or other hoist by the aid of a bull wheel attached to the mast, as shown in Fig. 327. The bull wheel is operated by ropes running to special slewing drums on the front of the engine. The bull wheel allows very rapid slewing of the boom and should be employed in such work as handling excavated materials or in placing concrete, where the derrick is in constant use for raising the materials and for swinging them through a large arc of a circle.

The mast of a guy derrick is held in an upright position by guy lines, usually five to seven in number, attached to the top of the mast at one end and to suitable anchorages at the other end (see Fig. 325). The boom of a guy derrick can revolve in a complete circle when the guys are anchored well out from the derrick and when making a small angle with the surface of the ground. When the guys are fastened to anchorages close in to the mast, the boom must be pulled up close to the mast to be revolved. For this to be done, the boom of a guy derrick must be several feet shorter than the mast.

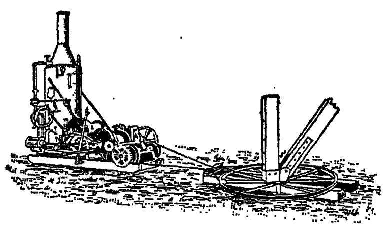


FIG. 327.—Bull wheel.

The foot of the guy derrick rests upon a pair of short timbers placed parallel to each other and with a space between for passage of the hoist and boom lines to the engine, as shown in Fig. 325.

The mast of a *stiff-leg* derrick is held in an upright position, as shown in Fig. 326, by inclined wooden struts, called "stiff legs," extending from the top of the mast to the sills. The stiff legs, as viewed in plan, are placed so as to form an angle of 90 degrees between them thus restricting the swing of the boom to three-fourths of a circle. The foot of the mast of a stiff-leg derrick rests upon the intersection of the two sill timbers which are connected at this point by a halved joint.

Erection of a Guy Derrick.—To erect a guy derrick, the boom and the mast are first completely rigged with the blocks, ropes, and fittings with which they will be permanently equipped, or the permanent guys to the mast top if desirable may be installed as will be explained later. The lower casting at the foot of the

mast together with the timbers to which it is secured are placed in position. The boom is erected in a temporary position first, and is used as a gin pole to erect the mast. To do this, it is first necessary to equip the top of the boom with temporary guys. This having been done, the boom is raised to a vertical position close to the mast casting by the same methods as are employed for raising a pin pole (Figs. 328 and 329). The same hoisting tackle at the end of the boom is used for raising it that is later employed for raising the derrick loads.

When the boom has been erected, the hoisting tackle is then in a position to be used for the erection of the mast. A sling, lashing, or chain is placed around the mast and the lower block of the boom tackle is attached to it (Fig. 330). Care should be taken in fixing the position of this sling to see that it is above the center of gravity of the mast but not so far toward the top of the mast as to prevent its being erected without the two tackle blocks coming together. The mast is raised to a vertical position (Fig. 331) and the foot is set in the casting. The permanent guys may now be installed if not already in position.

There are two different methods that can be employed for erecting the boom. The difference in the two methods lies in the

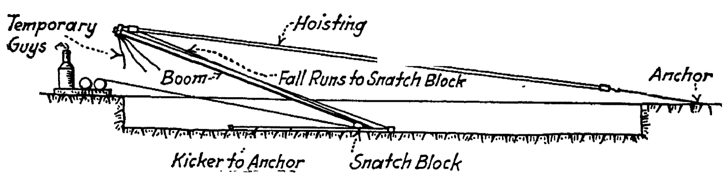


FIG. 328.—Erection of guy derrick.

arrangement of ropes and blocks. These two methods are represented in Figs. 328, 331, 332, and 333. The rope from the blocks in the boom must eventually be passed through the hole in the mast step casting. In the method of procedure outlined as method *A*, the reeving of the rope through the blocks must be changed after the boom is erected. In method *B*, the rope is taken off the drum of the engine and passed over the sheave in the boom and threaded through the mast step. In method *B*, a snatch block is attached near the top of the boom before it is erected, so as to be accessible later for erecting the mast. In this method, the permanent arrangement of blocks and ropes on the boom is retained during the erection of the derrick except

that the rope is passed through the snatch block previously mentioned, instead of over the sheave in the boom. After the

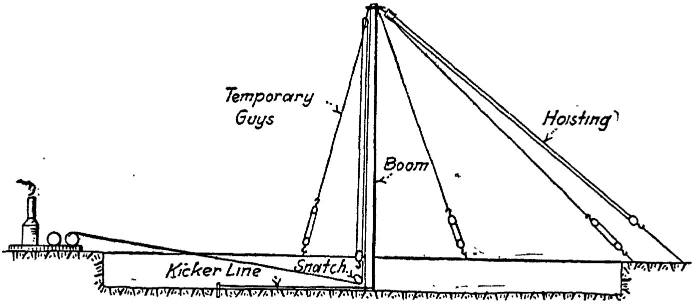


FIG. 329.—Boom erected as gin pole. Method *A*.

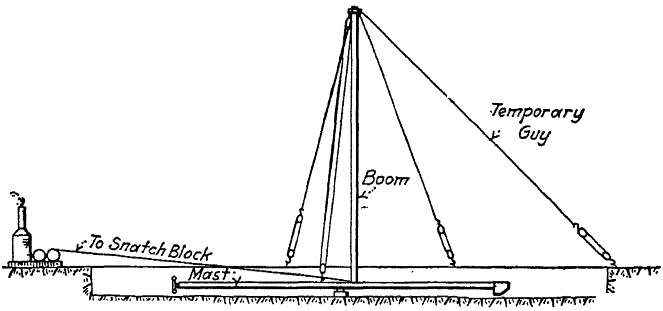


FIG. 330.—Erection of mast by boom. Method *A*.

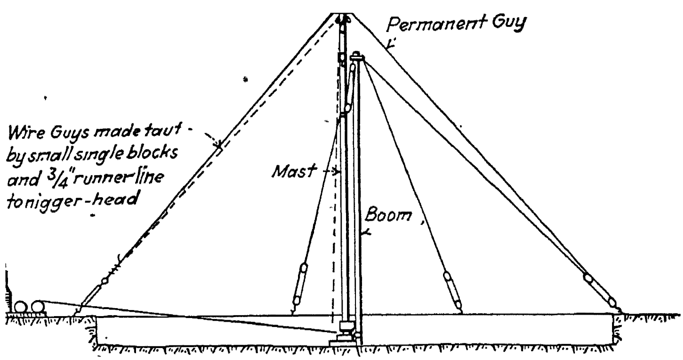


FIG. 331.—Mast erected by boom. Method *A*.

mast is erected, the rope is detached from the engine and passed over the sheave in the boom, threaded through the mast step, and secured to the drum of the engine. Previous to erecting the mast,

the rope of the topping lift tackle, attached to the mast, is passed through the hole in the mast step and footblock and brought to the engine. As the mast is raised, a man should be assigned

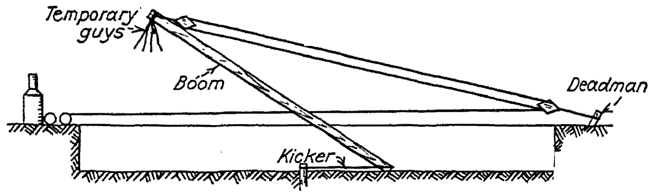


FIG. 332.—Erecting the boom. Method *B*.

to the task of pulling in the slack of this rope and to keeping it taut.

If wire-rope guys are to be used, it is customary to fasten two single blocks temporarily to the top of the mast on opposite sides before the mast is raised (Fig. 331). These blocks reeved with manila rope are used to raise the heavy wire-rope guys to the top

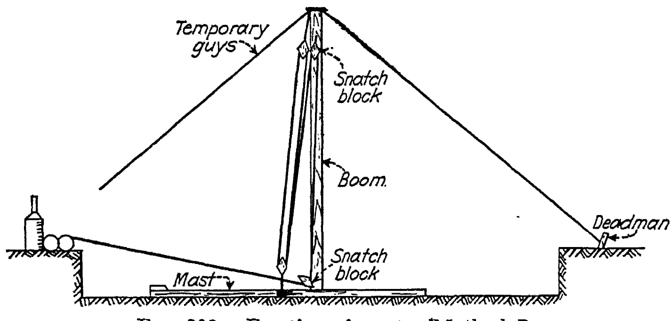


FIG. 333.—Erection of mast. Method *B*.

of the mast where they are made fast. Figure 335 shows the usual type of guy anchorage which is equipped with a sheave. The lower end of the guy is carried around the sheave and is fastened to the fall previously used to raise the other end of the guys. The guy is then pulled taut with this tackle and secured by wire-rope clips. Any subsequent adjustment may be made by screwing up the turnbuckle in the anchorage device.

Manila-rope guys may be pulled taut by the methods indicated in Figs. 302 and 304.

After the permanent-mast guys have been placed and tightened, the boom-lift tackle which is already fixed to the top of the mast is connected to its permanent fastening at the end of the boom,

and the latter is lifted and placed in its seat in the mast casting (Fig. 336).

When a short gin pole is used to erect a guy derrick, the proceeding is modified somewhat as the mast is erected first by the gin pole and the boom is connected while on the ground.

FIG. 334.—Guy tightener.

Elevating a Guy Derrick.—In erecting steel buildings several stories in height, it is necessary to raise the guy derricks to higher floors as the work of erecting the lower floors is completed. The method of accomplishing this is indicated in Figs. 337 and 338.

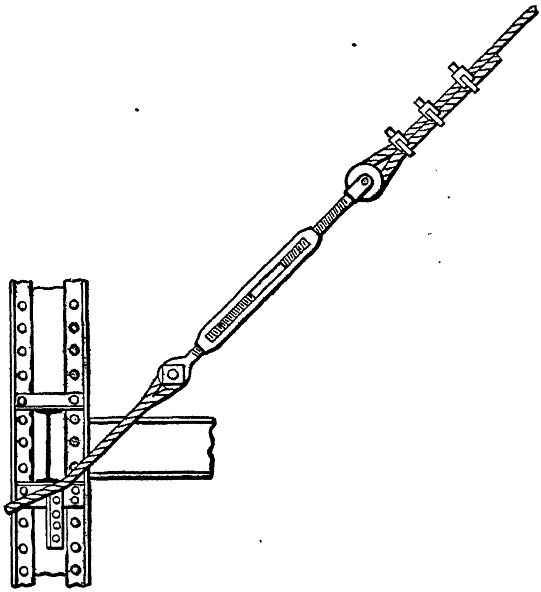


FIG. 335.—Guy anchorage or jumping sling.

The bottom of the boom is detached from the mast step and the boom is stood upright and guyed temporarily so as to act as a gin pole to elevate the mast. As the hoist tackle attached to the boom is used for this purpose, it is necessary to turn the boom around so that the tackle will face the mast. The boom-lift tackle connecting the top of the mast and the end of the boom is

not disconnected and becomes twisted in turning the boom around.

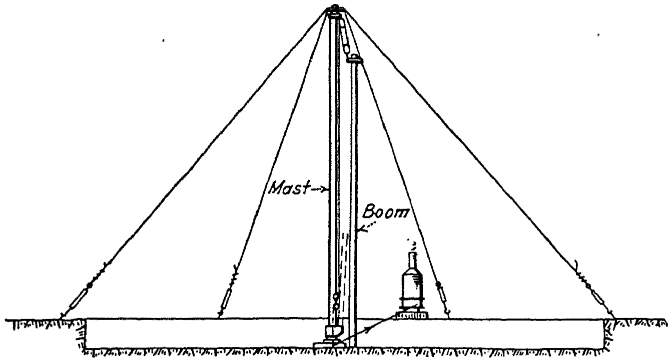


FIG. 336.—Boom about to be lifted into seat by mast.

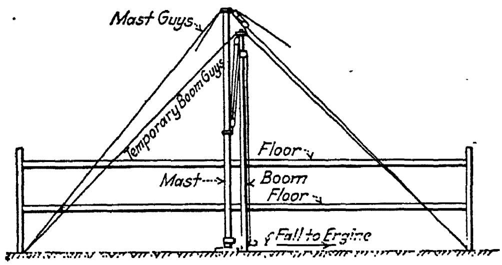


FIG. 337.—Elevating a guy derrick to higher floor. Lifting mast by boom.

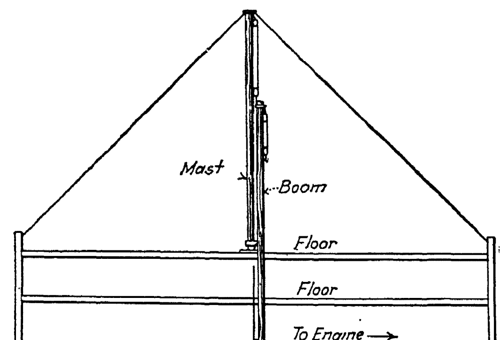


FIG. 338.—Elevating a guy derrick to higher floor. Lifting boom by mast.

A sling having been fastened around the mast and the mast guys having been unfastened, the mast is hoisted to its new position, the bottom casting and timbers attached to it being raised with it in the same operation. The mast is now seated and

guyed permanently in place. The boom is turned about to bring the tackles in their original position and is then raised by the boom-lift tackle.

Erection of Stiff-leg Derrick.—The stiff-leg derrick is erected in a manner that differs somewhat from that employed in erecting a guy derrick. The boom of a stiff-leg derrick is comparatively long as compared with the length of the mast, very often being half as long again, and for that reason it is inconvenient to use it for setting the mast. The mast of the ordinary stiff-leg derrick is seldom over 40 feet in height and, therefore, it is easily erected by a small gin pole or by a dutchman.

The derrick can be most quickly erected by a gin pole extending 5 or 6 feet above the top of the mast. With a gin pole of this

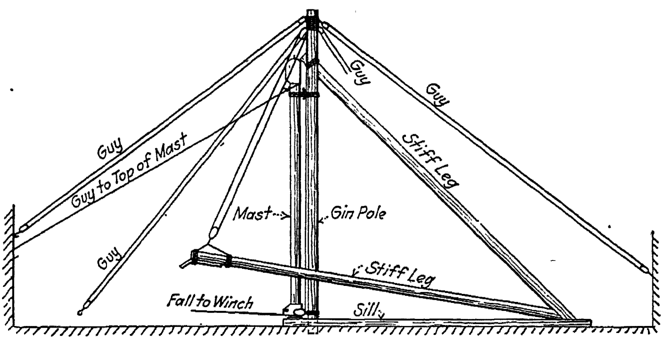


Fig. 339.—Erection of a stiff-leg derrick.

length, the various parts can be placed without moving the pole (Fig. 339). The pole is rigged and erected in the usual manner. A single block reeved with a small rope should be attached to the top of the pole above the lashings so that a man may be sent up when necessary to release a hook or to guide the stiff legs into place.

The pole should be erected close to the position to be occupied by the mast and within the angle formed by the stiff legs (Fig. 339). The sills and mast castings with all irons and bolts in place should be placed in position on the ground. The mast is then brought to the foot of the pole and a sling for raising it is placed around it close to the top. It should also be equipped with two guy lines to help steady it when in a vertical position. The mast is then raised and set in its place in the mast step casting. While still supported by the gin pole, the temporary guys on

the mast are made fast and the mast and gin pole are lashed together by two or three turns of rope near the top The hook of the hoisting tackle may then be disengaged from the mast and lowered for raising the stiff legs.

One of the stiff legs is then brought into position and its lower end is joined to the sill. A sling or lashing is placed around the extreme top end of the stiff leg and it is raised to the top of the mast; the gooseneck iron is guided into position over the gudgeon pin. The stiff leg is then lashed fast to the gin pole. If it is

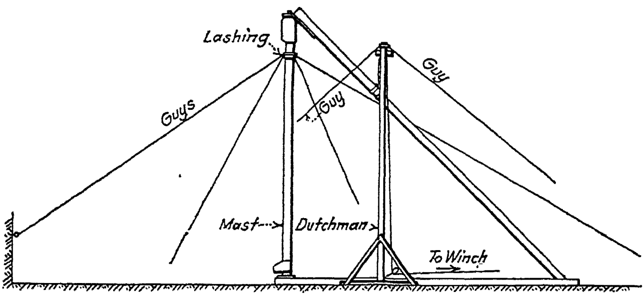


FIG. 340.—Erection of a stiff-leg derrick.

necessary to turn the mast around for any reason, it may be easily done by a bar thrust through the hole in the boom seat. The second stiff leg is then erected in a similar manner.

A stiff-leg derrick may be erected by using a short gin pole or a dutchman but, in such a case, it is necessary to move the pole two or three times as each stick must be lifted by a sling just above the middle of the stick (Fig. 340). A dutchman completely rigged with sheaves and a winch is particularly convenient to use. The dutchman should be located close to the mast and in the angle formed by the stiff legs. It is necessary to place the sling lower on the mast than when using a pole longer than the mast. After the mast has been erected the dutchman must be moved to erect the stiff legs. The stiff leg is lifted by a sling slightly above the middle of the leg; its position and that of the dutchman depend upon the height of the latter.

After the mast and stiff legs have been erected and completely fitted with irons, the boom is laid on the ground with the lower end secured in the boom seat. The derrick is then equipped with blocks and sheaves and the hoist line and boom fall are reeved through them.

The power for raising the different parts of a derrick may be best supplied by a crab on the ground. The gin pole can usually be raised by man power applied to the tackle in one or two of the guy lines.

Jinniwink.—A jinniwink derrick is shown in Fig. 341. A jinniwink is very useful for light hoisting. It can be bought in 3- or 5-ton capacity and may be operated by man power or by a power unit. The jinniwink finds its greatest field of usefulness in steel erection work. The derrick is erected on the steel floor beams and the two sill timbers are lashed securely to the beams. Hand-powered jinniwinks are preferably rigged with manila rope. Those operated by a power unit should be rigged with cable.

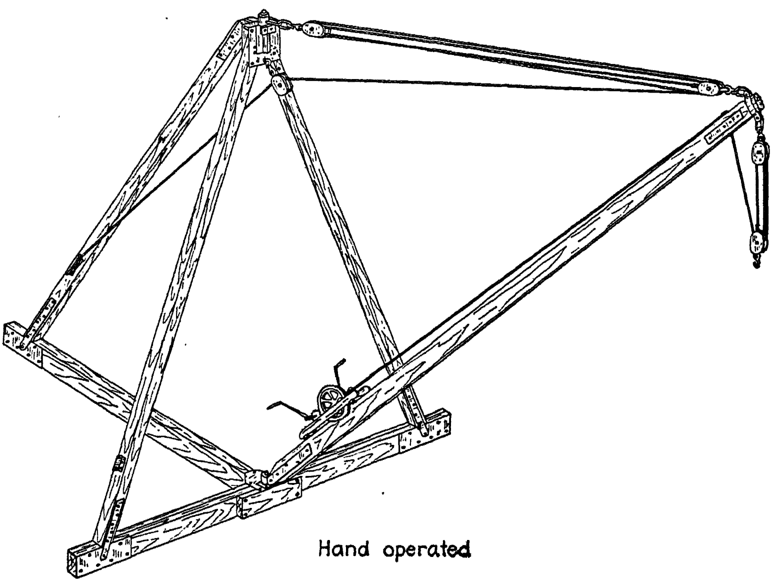


FIG. 341.—A jinniwink.

When a jinniwink is used on steel erection work, the front sill and tail sill are customarily lashed to the floor beams. Links are provided at the top of the derrick for two or three rear guys. One guy, consisting of a small tackle, is usually kept attached and is useful when the derrick is moved. Where it is not practical or desirable to lash the sills down, the derrick can be guyed with three guys. In such cases, the tail sill must be weighted down or it will rise when the strain from the load pulls the sag

out of the rear guy. A flooring of planks is laid across the tops of the beams and the jinniwink is moved over this flooring.

WINCHES

Winches.—Winches are designed for use with manila rope or with wire rope. The drum of a winch intended for use with manila rope (Fig. 342) is smaller in diameter and longer than a drum intended for wire rope (Fig. 343). A drum for manila rope

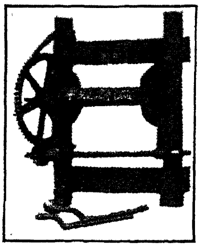


FIG. 342.—Winch for manila rope. Pull of one man on single line, 1 ton.

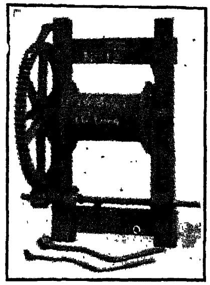


FIG. 343.—Winch for wire rope.

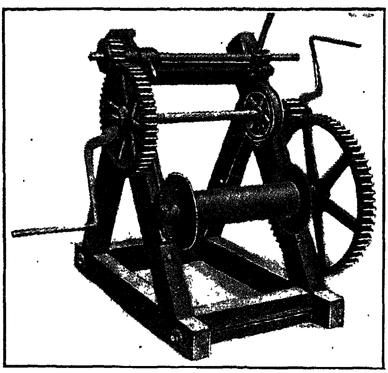


FIG. 344.—Double-purchase winch. Pull of one man on single line, 3000 pounds.

is about 4 to 6 inches in diameter and 24 inches in length or longer. A drum for wire rope is about 9 or 10 inches in diameter and 16 or 20 inches in length.

A crab is a winch constructed with a triangular frame and intended to be operated while upon the ground, although the designation "winch" is commonly given to all varieties of these machines (Fig. 344).

A cylindrical drum such, as shown in Figs. 342 and 343, is not, strictly speaking, well adapted to the use of manila rope. A rope on these drums is fastened at the end to the drum. As the drum revolves the rope winds up on it, traveling toward the end of the drum; then reversing, it travels toward the other end. At each reversal and often between, the rope will ride on the previous turns and if it slips off, it gives a sharp jerk to the load line. When hoisting a heavy load, the rope on the drum is squeezed and subjected to considerable wear.

The drum which is best shaped for the use of manila rope has a concave surface (Fig. 345). The rope is not fastened to this style of drum. It is passed three or four turns around the drum, the free end of the rope being held by a man, who pulls in the slack as a load is lifted. This cannot be done with a cylindrical drum. Drums of this shape were formerly in common use. They are now seldom seen on hand winches due probably to the increasing use of wire rope.

The gear cogs are the weakest part of an ordinary winch. The gears are usually made of cast iron and it is possible for the cogs to be broken when hoisting heavy loads. Winches with steel gears can be obtained but usually have to be made to order.

A winch is equipped with two handles or cranks, one for each side of the machine. It is so designed that its lifting capacity is developed by one man on each crank. More men on the cranks simply make the labor of hoisting easier. This permits a fair check for discovering unusual friction caused by snub lines or any condition that might tend to throw an excessive load on the hoisting tackle.

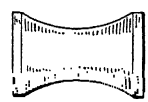


FIG. 345.—Concave surge drum for manila rope.

CHAIN HOIST

The chain hoist provides a convenient and efficient method of hoisting by hand (Fig. 346). It can be operated by one man and will raise loads weighing several tons. One of its great outstanding advantages over ordinary tackle is that, when a load is suspended on a chain hoist, it will be sustained at that level safely and without requiring any attention; whereas a load lifted by ordinary tackle can only be kept suspended by making the fall fast to some object as an anchorage. Another advantage of the chain hoist that is apparent in machine erection, pipework, and the like, is that the slow travel of the lift allows minute adjust-

ments of height to be made and, for the same reason, permits the load to be deposited gently.

In using the chain hoist, it should be borne in mind that the ordinary hoist of this kind has a lift of only 8 or 10 feet and, if the load is to be raised to greater heights, suitable arrangements will have to be made to support it while the hoist is being adjusted to continue the lift. For long lifts, chain hoists with long chains should be bought. If the hoist is to be used in industrial plants for general erection purposes, it should be equipped with chains for a 30-foot lift.

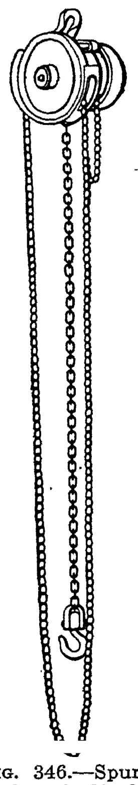


FIG. 346.—Spur-geared chain block.

Sling Chains.—Sling chains will be found useful in erection work for handling loads, for forming fastings for tackle and guys, and in a great many other ways. They are made ordinarily with a round hook at one end of the chain and a large ring at the other end, but chains may also be procured that are equipped with a grab hook and ring or with a round hook at one end and a grab hook at the other. These varieties of hooks are shown in Fig. 347.

The round hook has a wide opening which allows it to fit around the chain and form a slip noose around a load. The grab hook is shaped with a long, narrow opening exactly fixed so that a link of the chain may be inserted edgewise into it, forming a non-slip loop which holds securely. Table 25 gives safe working loads for chains of various diameters of metal. Chains used constantly for heavy work should be annealed every month or two. Bridle chains (Fig. 348) may be used advantageously for handling objects with derricks and locomotive cranes and may be obtained with hooks of either shape.

The safe load in tons that can be supported by a chain can be computed by the empirical formula $L = 10D^2$ where L is the load in tons and D is the diameter of the metal stated in inches.

JACKS

Ratchet Jack.—The ratchet jack, shown in Fig. 349, is commonly in use for a variety of purposes in setting machinery,

boilers, and in similar work. This type of jack has a capacity of 10 to 50 tons. It may be operated so as to lift with the top

TABLE 25.—SAFE CAPACITIES OF CHAINS

Diameter of iron, inches	When used straight	When used at 60-degree angle	When used at 45-degree angle	When used at 30-degree angle
1/4	1,330	1,000	850	600
3/8	2,660	2,050	1,700	1,200
1/2	5,330	4,100	3,400	2,400
5/8	8,330	6,800	5,600	4,000
3/4	12,000	9,400	7,800	5,500
7/8	16,330	12,800	10,400	7,400
1	20,830	16,000	13,000	9,400

of the jack or with the projection at its foot. When jacking against an iron surface, a piece of board or plank should be inserted between the bearing portions of the jack and the object

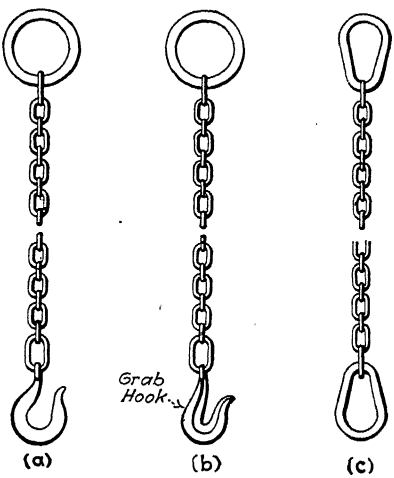


FIG. 347.—Sling chains.

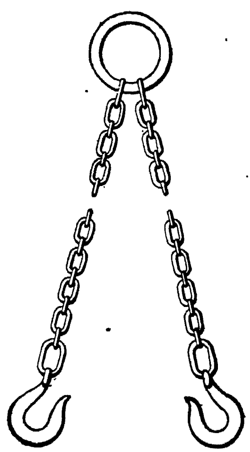


FIG. 348.—Bridle chain.

to be raised to prevent the metal surfaces from sliding on each other. The jack should be placed so as to bear squarely at each end otherwise it is likely to kick out of place with tremendous force.

A considerable amount of time is consumed in raising an object 1 or 2 feet with this type of jack as the operation requires an endless amount of maneuvering with timber blocking. The object unless very heavy may be raised more satisfactorily by chain blocks hung from suitable heavy timber supports.

Ratchet jacks are frequently used in rigging work to raise or lower heavy and bulky objects onto skids, as indicated in Fig.

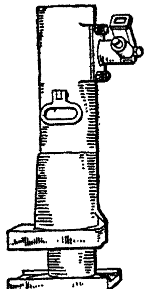


FIG. 349.—Ratchet jack.

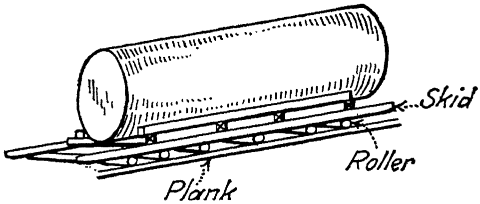


FIG. 350.—Steel shell on skids.

350. A surprising gain in time and ease in accomplishing this operation may be had by the use of two jacks, as shown in Fig. 351 which shows a steel shell about to be lowered onto skids and rollers. Objects constructed of thin plates such as smokestacks and other steel shells should never be jacked against directly, as the surface of the shell will be indented by the concentrated force of the jack at one point. The use of two jacks and a suitable arrangement of timbers, as shown in Fig. 351, will spread the pressure in such a manner as to avoid damage to the shell.

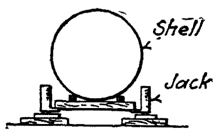


FIG. 351.—Lifting heavy shell with two jacks.

Screw Jack.—The screw jack, shown in Fig. 353, is the type of jack used for raising buildings and roofs and is operated by turning the screw by means of a short piece of pipe or bar of iron inserted in the holes provided in the head casting. The screw jack is used always in conjunction with jacking timbers, as indicated in Fig. 354.

The lift of a jack screw is only 16 or 18 inches. When raising an object through a distance of several feet, the jack will have to be moved to a higher level several times. The operation of raising with the jack has to be followed up closely by the insertion of timber blocking, which serves as a support for the object

and also for the jack. Figure 354 shows such an arrangement of timbers. It will be seen that 1-inch boards are inserted between

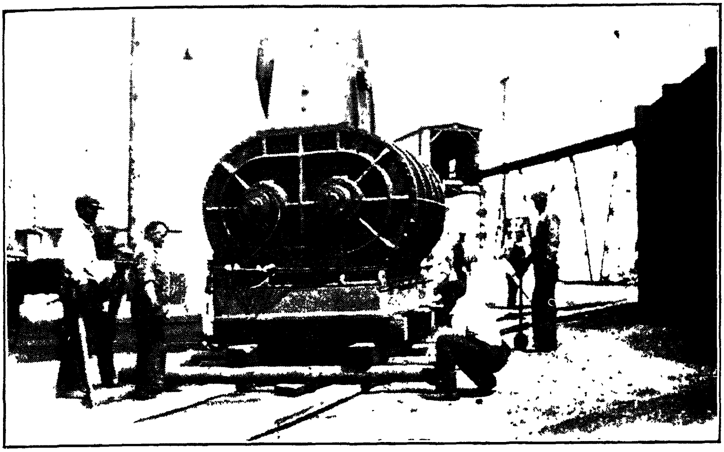


FIG. 352.—Transporting a machine on rollers.

the timbers to provide space so that the jacking timbers may be withdrawn and inserted at a higher level as the object is raised.

A building or roof when raised several feet in this manner will often move horizontally out of position, at times as much as

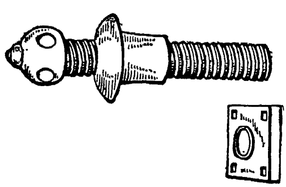


FIG. 353.—Screw jack.

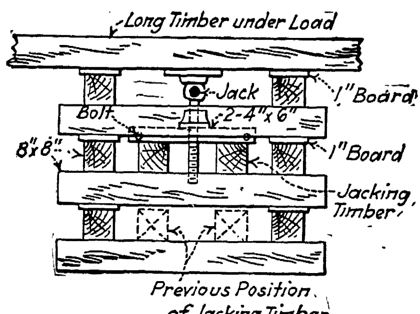


FIG. 354.—Raising a load with a screw jack.

several inches. It may be brought back into position by "tripping" the jacks. As may be seen, the screw jack is formed of several separate parts. The top casting resting upon the head of the screw is entirely loose from the remainder of the jack and fits over the head of it, forming a ball-and-socket joint. To move an object horizontally, the jack is loosened and the top casting

and the head of the jack are pushed to one side so that the stem is caused to depart from a perpendicular position. The jack is then screwed tight. The pressure causes the jack to work back to a vertical position, moving its load with it laterally as it rights itself.

HOUSE MOVING

The operation of moving a building is illustrated in detail in Figs. 355 and 356. The first thing to be done in preparation for moving a building is to break several holes in the foundation

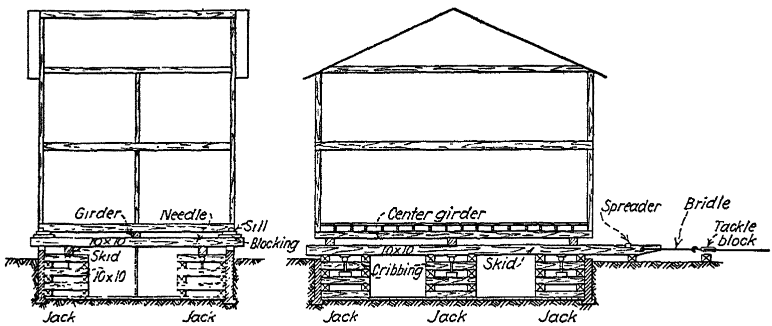


FIG. 355.—House moving.

walls for the insertion of the heavy timbers that are to carry the building during its transit from one location to another.

It will be seen upon an inspection of the figure that the main timbers used consist of two long skid timbers and several needle timbers. Several screw jacks are required, some strong rope, tackle blocks, and a generous supply of timber blocking.

The number of needle timbers used will depend on the length of the building and the weight of it. The more needles there are the less cracking of plaster there will be. The needles should be close enough together to prevent the house sills and center girder from bending. A simple and desirable arrangement would be obtained if the needles could be placed directly against the under side of the house sills but usually there is a center girder, supporting the first floor joists, that projects downward to a level a few inches lower than the under side of the sills. The usual practice is to bring the needles to bear against the under side of the center girder and to fill the spaces between the needles and the house sills with blocking. This is indicated in the

illustration. The skids and needles should preferably be 10-by-10 or 12-by-12 timbers.

To lift the building clear of the foundation walls, it is necessary to use several screw jacks, with jacking timbers, supported on sets of cribbing. The cribbing lumber can be of any convenient size. Timbers measuring 8 or 10 inches on a side are convenient to handle. They may be about 5 feet long. The sets of cribbing should be placed just inside the foundation walls. There should be two jacks and two sets of blocking under each needle. The jacks are operated as explained in connection with Fig. 354.

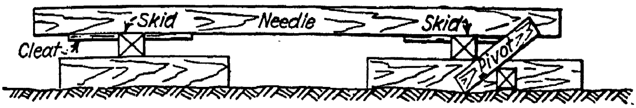


FIG. 356.—Steering the skids.

The building is raised clear of the foundations with the jacks until the bottom of the skids are a few inches above the ground. The tops of the cribbing timbers are then given a generous coating of grease and the building is lowered until the skids rest on the greased timbers. A number of loose timbers are laid on the ground for the skids to slide upon. The tops of these timbers are brought level and coated with grease.

The front ends of the skids should be prepared for pulling the building by equipping them with a pulling bridle made of wire rope. To keep the bridle from drawing the skids together, a spreader timber should be cut in between them as shown in the figure. The needles can be cleated against the skids to hold them in place. A motor truck may be used to provide the pulling power. It is necessary to connect it with a bridle and a tackle containing several parts of rope. This is to diminish the tendency of the truck to jerk the building when pulling.

When moving the structure forward, it will usually be necessary to change the direction of travel and to steer the skids in the desired direction. This can be done by wedging a short timber against the edge of one of the skids as shown in Fig. 356. When pulling is resumed, the timber will act as a pivot against which the skids will turn.

CHAPTER XII

PIPEWORK

General.—The selection of the variety of pipe to be used in any location is controlled by the capacity required and by the pressure to which the pipe will be subjected. It is also influenced by by the position of the pipe depending upon whether it is to be underground or not. Fortunately, where pipes of large capacity are necessary the pressure is usually comparatively light; that is, under 75 pounds. Such conditions exist in pipes conveying water, in gas mains, and in exhaust steam lines. In similar fashion, where the pressures to be resisted are high, usually a pipe of small capacity is suitable. Such conditions exist in pipes conveying live steam or compressed air.

While cast-iron pipe is well adapted for any work where the pipe will be buried in the ground and steel pipe is best adapted for purposes where the pipe will be suspended in the air, nevertheless, each variety is used in both locations, the selection being influenced by other considerations. It may be said in a general way that steel pipe is most suitable for high pressures, while the use of cast-iron pipe is generally restricted to pressures below 100 pounds.

Steel pipes are frequently placed in the ground and, while it is not an ideal combination, they usually will give fair service there. Wrought-iron pipes resist rust better than steel pipes when buried underground and consequently should always be used in that location in preference to steel pipe.

Cast-iron, Bell-and-spigot Pipe.—Cast-iron bell-and-spigot pipes are commonly employed where pipes of large size are to be placed in the ground. Cast iron is attacked very slowly by corrosion, and the bell-and-spigot joint made up with either molten lead or neat cement will resist successfully any strains likely to be thrown upon it in its position in the ground.

Pipes with bell-and-spigot joints are frequently used above ground in installations subjected to light pressures. They may be used to very good advantage in some situations, as this type of

pipe permits considerable adjustment to be made in matters of distance and direction. There is an adjustment of about ½ inch in length to be gained in each bell, and a slight change in direction is also possible at this point. If greater adjustment in distance is necessary than can be gained in the bells, a length of pipe can be cut to the desired length.

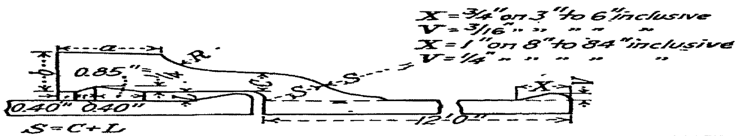
Valves in lines of bell-and-spigot pipe may be installed with bell-and-spigot joints or they may have flanged connections. The bell-and-spigot joint, of course, is not as susceptible to rust as the bolted flange joint, but the rate of deterioration due to rusting of the bolts in a flanged joint is very slow and a bolted joint will last a great number of years. When valves are inclosed in valve boxes or pits with masonry walls, the flanged valve is suitable. The bolted flange joint has a decided advantage in that the valve is easily removed for overhauling and repairs. When flanged connections are used with bell-and-spigot pipe, the two joints are connected by a piece of flange-spigot pipe 1 or 2 feet long.

Standards.—Bell-and-spigot pipes are cast to standard dimensions that have been adopted by various associations of manufacturers and users of pipe as being most suitable for their needs. The principal standards are those for soil pipe, for gas pipe, and for water pipe.

In a general way all bell-and-spigot pipes are similar in form. Bell-and-spigot pipes made for conveying water, gas, and for similar purposes are cast vertically in the molds and may be distinguished easily, on this account, from cast-iron soil pipes. Soil pipes are cast in a horizontal position. This method of casting forms ridges along the sides of the soil pipes which may be readily seen. Water pipes are always given a coating of asphaltum pitch. Gas pipes are always furnished uncoated.

Bell-and-spigot water and gas pipes, also, are cast in standard laying lengths of 12 feet, unless ordered in special lengths. This length does not include the depth of bell, the over-all length being from 4 to 5 inches longer. Cast-iron soil pipe is cast in laying lengths of 5 feet. Figure 357 shows a section through a standard bell-and-spigot pipe cast to the specifications of the American Water Works Association. The table gives standard dimensions for each size of pipe.

Fittings.—Changes of direction in a line of pipe when slight may be made by deflecting each length of pipe from a straight

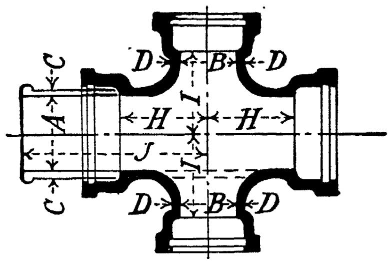


Nominal diam., inches	Classes	Actual outside diam., inches	Diam. of sockets		Depth of sockets		A	B	C
			Pipe inches	Special castings, inches	Pipe inches	Special castings, inches			
4	A	4.80	5.60	5.70	3.50	4.00	1.5	1.30	.65
4	B—C—D	5.00	5.80	5.70	3.50	4.00	1.5	1.30	.65
6	A	6.90	7.70	7.80	3.50	4.00	1.5	1.40	.70
6	B—C—D	7.10	7.90	7.80	3.50	4.00	1.5	1.40	.70
8	A—B	9.05	9.85	10.00	4.00	4.00	1.5	1.50	.75
8	C—D	9.30	10.10	10.00	4.00	4.00	1.5	1.50	.75
10	A—B	11.10	11.90	12.10	4.00	4.00	1.5	1.50	.75
10	C—D	11.40	12.20	12.10	4.00	4.00	1.5	1.60	.80
12	A—B	13.20	14.00	14.20	4.00	4.00	1.5	1.60	.80
12	C—D	13.50	14.30	14.20	4.00	4.00	1.5	1.70	.85
14	A—B	15.30	16.10	16.10	4.00	4.00	1.5	1.70	.85
14	C—D	15.65	16.45	16.45	4.00	4.00	1.5	1.80	.90
16	A—B	17.40	18.40	18.40	4.00	4.00	1.75	1.80	.90
16	C—D	17.80	18.80	18.80	4.00	4.00	1.75	1.90	1.00
18	A—B	19.50	20.50	20.50	4.00	4.00	1.75	1.90	.95
18	C—D	19.92	20.92	20.92	4.00	4.00	1.75	2.10	1.05
20	A—B	21.60	22.60	22.60	4.00	4.00	1.75	2.00	1.00
20	C—D	22.06	23.06	23.06	4.00	4.00	1.75	2.30	1.15
24	A—B	25.80	26.80	26.80	4.00	4.00	2.00	2.10	1.05
24	C—D	26.32	27.32	27.32	4.00	4.00	2.00	2.50	1.25
30	A	31.74	32.74	32.74	4.50	4.50	2.00	2.30	1.15
30	B	32.00	33.00	33.00	4.50	4.50	2.00	2.30	1.15
30	C	32.40	33.40	33.40	4.50	4.50	2.00	2.60	1.32
30	D	32.74	32.74	33.74	4.50	4.50	2.00	3.00	1.50
36	A	37.96	38.96	38.96	4.50	4.50	2.00	2.50	1.25
36	B	38.30	39.30	39.30	4.50	4.50	2.00	2.80	1.40
36	C	38.70	39.70	39.70	4.50	4.50	2.00	3.10	1.60
36	D	39.16	40.16	40.16	4.50	4.50	2.00	3.40	1.80
42	A	44.20	45.20	45.20	5.00	5.00	2.00	2.80	1.40
42	B	44.50	45.50	45.50	5.00	5.00	2.00	3.00	1.50
42	C	45.10	46.10	46.10	5.00	5.00	2.00	3.40	1.75
42	D	45.58	46.58	46.58	5.00	5.00	2.00	3.80	1.95
48	A	50.50	51.50	51.50	5.00	5.00	2.00	3.00	1.50
48	B	50.80	51.80	51.80	5.00	5.00	2.00	3.30	1.65
48	C	51.40	52.40	52.40	5.00	5.00	2.00	3.80	1.95
48	D	51.98	52.98	52.98	5.00	5.00	2.00	4.20	2.20
54	A	56.66	57.66	57.66	5.50	5.50	2.25	3.20	1.60
54	B	57.10	58.10	58.10	5.50	5.50	2.25	3.60	1.80
54	C	57.80	58.80	58.80	5.50	5.50	2.25	4.00	2.15
54	D	58.40	59.40	59.40	5.50	5.50	2.25	4.40	2.45
60	A	62.80	63.80	63.80	5.50	5.50	2.25	3.40	1.70
60	B	63.40	64.40	64.40	5.50	5.50	2.25	3.70	1.90
60	C	64.20	65.20	65.20	5.50	5.50	2.25	4.20	2.25
60	D	64.82	65.82	65.82	5.50	5.50	2.25	4.70	2.60
72	A	75.34	76.34	76.34	5.50	5.50	2.25	3.80	1.87
72	B	76.00	77.00	77.00	5.50	5.50	2.25	4.20	2.20
72	C	76.88	77.88	77.88	5.50	5.50	2.25	4.60	2.64
84	A	87.54	88.54	88.54	5.50	5.50	2.50	4.10	2.10
84	B	88.54	89.54	89.54	5.50	5.50	2.50	4.50	2.60

FIG. 357.—Standard dimensions of cast-iron pipe.

line as it is laid. The possible deflection for each 12 feet length is greater for small pipes than for those of large diameter. Changes of direction greater than those obtained by the above method are accomplished by the use of standard fittings which are made at angles of 90, 45, 22½, and 11¼ degrees. They are known, respectively, as an elbow, a one-eighth, a one-sixteenth, and a one-thirty-second bend.

Connections between pipe lines are made by standard fittings known as crosses, tees, and 45-degree branches. The end of a



Nominal diam., inches		Class	Dimension, inches			Approximate weights, pounds			
						3-Way branches		4-Way branches	
A	B		H	J	I	2 Bells	3 Bells	3 Bells	4 Bells
4	3	D	11	23	11	121	120	153	153
4	4	D	11	23	11	125	128	164	166
6	3	D	12	24	12	173	170	207	204
6	4	D	12	24	12	185	183	223	221
6	6	D	12	24	12	203	200	259	257
8	4	D	13	25	13	262	255	301	294
8	6	D	13	25	13	278	270	333	325
8	8	D	13	25	13	301	294	378	372
10	4	D	14	26	14	356	338	395	377
10	6	D	14	26	14	371	352	424	406
10	8	D	14	26	14	389	371	461	443
10	10	D	14	26	14	414	395	511	493
12	4	D	15	27	15	473	445	514	486
12	6	D	15	27	15	486	458	540	512
12	8	D	15	27	15	502	474	573	545
12	10	D	15	27	15	519	491	605	577
12	12	D	15	27	15	540	512	651	623
15	4	B	16	28	16	485	480	535	530
14	4	D	16	28	16	614	588	666	641
14	6	B	16	28	16	500	495	560	555
14	6	D	16	28	16	634	608	730	700
14	8	B	16	28	16	515	510	600	595
14	8	D	16	28	16	662	636	787	761
14	10	B	16	28	16	535	525	635	625
14	10	D	16	28	16	679	653	822	796
14	12	B	16	28	16	560	550	680	670
14	12	D	16	28	16	698	672	860	834
14	14	B	16	28	16	575	569	723	715
14	14	D	16	28	16	750	724	938	963
16	4	B	17	29	17	615	610	675	670

FIG. 358.—Standard cast fittings.

line of pipe may be closed by a fitting known as a plug, which is inserted in the bell or by a cap which is placed over a spigot end. Two spigots may be joined by a double-bell fitting known as a "double hub" or by a sleeve. Two bell ends may be connected together by a length of spigot-spigot pipe.

A change in sizes may be easily made at any point in a line of pipe by means of a reducing fitting. Reducing fittings may be either concentric or eccentric. Concentric reducers preserve the same center line. Eccentric reducers permit the inverts or bottoms of the pipes to be kept at the same level.

Cast-iron bell-and-spigot pipe fittings are made in standard shapes with a fixed number of bells and spigots, as in the standard

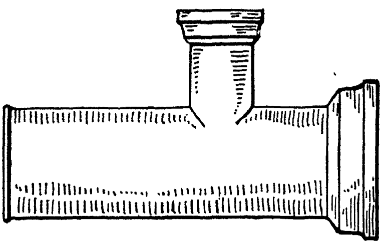


FIG. 359.—A 12- by 6-inch tee—bell, spigot, bell.

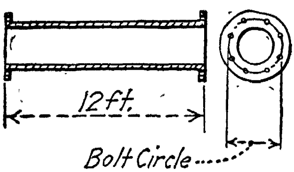


FIG. 360.—Flanged cast-iron pipe.

cross or tee, shown in Fig. 358. When cast differently they are classed as special castings for which an extra price is charged. In Fig. 359, a special tee is shown, which is described technically as a 12- by 6-inch tee; bell, spigot, bell; or as represented by symbols 1–12″ × 6″ tee B.S.B. The figures represent diameters and the letters designate bell and spigot, the run of the pipe being stated first and the branch last. Similar methods are followed with the other fittings.

It is preferable, when ordering bell-and-spigot fittings to order all tees with three bells. To a less degree the same thing is true of elbows and bends. Numerous bell ends on the fittings are advantageous where pipes have to be cut to odd lengths, as several short lengths of spigot-spigot pipe can be cut from a standard 12-foot length of pipe but only one piece of pipe with a bell end is available.

Flanged Cast-iron Pipe.—Cast-iron pipe with flanged joints is used almost entirely for installations above ground and is employed where pipes of large capacity are required (Fig. 360).

The bolted flange connections possess great structural strength and rigidity and, for that reason, the flanged pipe is well adapted to suspension from hangers and brackets or for use in vertical runs. Where the joint is made up with bolts having hexagonal nuts and of a length such that the bolt just fills the nut, this style of pipe presents a very attractive appearance. In situations where it is desirable to have pipe which may be easily taken apart, the flanged pipe will be found suitable.

One of the chief objections to the use of flanged cast-iron pipe is the fact that accurate work is required in planning installations of such pipe as practically no adjustment of length or direction is possible. Flanged cast-iron pipe cannot be cut in lengths to suit conditions as with bell-and-spigot pipe. As soon as the first one or two lengths of pipe are placed, the direction of the center line is established by the rigid flanges and little deviation from a straight line is obtainable. This characteristic of flanged cast-iron pipe usually requires extremely careful work on the part of the men installing the pipe.

Flanged cast-iron pipe is usually of large diameter. Like the bell-and-spigot pipe the flanged pipe is cast in various weights and with dimensions to agree with standards adopted by various committees. The number and size of bolts and the diameter of bolt circle varies with each standard. The standard length face to face of flanges is 12 feet. The flanges are faced smooth at right angles to the axis of the pipe. They are drilled with bolt holes in multiples of four, the flanges having from 4 to 32 holes depending on the diameter of the pipe. The holes should be drilled 1/8 inch larger in diameter than the bolts. The bolts may have square heads but should have hexagonal nuts so that they may be more conveniently turned up with a wrench.

Fittings.—Changes in direction of a line of flanged pipe can only be made by using standard or special fittings. Slight changes in direction may be made by inserting a beveled ring of iron, known as a "dutchman." A dutchman, however, is unsightly and should only be made use of as a last resort.

The fittings for flanged pipe are similar to those for bell-and-spigot pipe. The working dimensions, that is, the distance from face of flange to face of flange and the distance from the bottom of bell to the bottom of bell is the same for fittings of all shapes of 16 inches and over in diameter. This allows alterations

to be made in existing pipe lines changing from bell and spigot to flanged fittings and *vice versa,* substituting where necessary one fitting in place of another; such as a tee for an elbow and so on. The bolt holes in standard fittings and valves are drilled so as to straddle the vertical and horizontal center lines. This, together with drilling in multiples of four, permits them to be turned in any quarter of a circle. The positions of these holes with respect to the center lines have to be watched carefully in some conditions of pipework.

Threaded Pipe.—Steel pipe with threaded joints is best adapted for installations where the piping is above ground. When steel pipes are placed in the ground they usually give satisfactory service and resist rusting for a number of years. In some soils they will last a long time; in others they will rust through in one or two years. In cinders, steel pipes are rapidly eaten away. Sulphur in the cinders, in the presence of moisture, is turned into sulphuric acid which immediately attacks the metal of the pipes.

There is a difference in the lasting power of wrought-iron pipe and steel pipe when subjected to underground conditions favorable to rusting. In this respect wrought-iron pipe is very dependable.. When laid underground it lasts indefinitely. After being buried underground for periods of 20 years or more, it will usually be found to be still in good condition.

Steel piping that is to be placed in the ground or in positions where it will be subjected to dampness should be galvanized.

Steel pipes with threaded joints are useful for work where small capacities are sufficient or where heavy pressures have to be resisted. They have the additional advantages of lightness and cheapness. Steel pipes may be readily cut or bent and may be joined together with small standard fittings so as to run in any desired direction.

Wrought-iron and steel pipe with screwed fittings may be obtained in three grades: as standard-strength pipe, as extra-strong pipe, and as double-extra-strong pipe. They may be procured in all sizes from 1/8 to 15 inches nominal internal diameter in standard-strength pipe. Standard-strength pipe is often termed standard-full-weight pipe. Extra-strong pipe may be obtained in all sizes from 1/8 to 12 inches nominal diameter. Double-extra-strong weight pipe may be obtained in all sizes from 1/2 to 8 inches diameter (Tables 26 and 27).

TABLE 26.—"STEEL" PIPE, FULL STANDARD WEIGHT—BLACK AND GALVANIZED

(All Weights and Dimensions are Nominal)

Size in inches	Diameters		Thickness	Weight per foot		Threads per inch
	External	Internal		Plain ends	Threads and couplings	
1/8	0.405	0.269	0.068	0.244	0.245	27
1/4	0.540	0.364	0.088	0.424	0.425	18
3/8	0.675	0.493	0.091	0.567	0.568	18
1/2	0.840	0.622	0.109	0.850	0.852	14
3/4	1.050	0.824	0.113	1.130	1.134	14
1	1.315	1.049	0.133	1.678	1.684	11½
1¼	1.660	1.380	0.140	2.272	2.281	11½
1½	1.900	1.610	0.145	2.717	2.731	11½
2	2.375	2.067	0.154	3.652	3.678	11½
2½	2.875	2.469	0.203	5.793	5.819	8
3	3.500	3.068	0.216	7.575	7.616	8
3½	4.000	3.548	0.226	9.109	9.202	8
4	4.500	4.026	0.237	10.790	10.889	8
4½	5.000	4.506	0.247	12.538	12.642	8
5	5.563	5.047	0.258	14.617	14.810	8
6	6.625	6.065	0.280	18.974	19.185	8
7	7.625	7.023	0.301	23.544	23.769	8
8	8.625	8.071	0.277	24.696	25.000	8
8	8.625	7.981	0.322	28.554	28.809	8
9	9.625	8.941	0.342	33.907	34.188	8
10	10.750	10.192	0.279	31.201	32.000	8
10	10.750	10.136	0.307	34.240	35.000	8
10	10.750	10.020	0.365	40.483	41.132	8
11	11.750	11.000	0.375	45.557	46.247	8
12	12.750	12.090	0.330	43.773	45.000	8
12	12.750	12.000	0.375	49.562	50.706	8
13	14.000	13.250	0.375	54.568	55.824	8
14	15.000	14.250	0.375	58.573	60.375	8
15	16.000	15.250	0.375	62.579	64.500	8

Soft-steel pipe is largely used in place of wrought iron, though the latter is less subject to corrosion. The steel pipe possesses a strength which is half as great again as that of wrought iron. Steel and wrought-iron pipe is made of butt-welded tubing up to 3 inches in diameter; larger sizes are lap welded. Steel pipe is always tested at the mill. Each length of standard-strength pipe is subjected to a hydrostatic pressure of 500 pounds; extra strong and double extra strong pipe are tested with pressures ranging between 700 and 2000 pounds.

All sizes are stated in nominal diameter, although the actual internal diameter is somewhat different. The same external diameter is maintained for all three grades of pipe, the difference in thickness affecting the internal diameter only. This permits the use of the same fittings on all three weights of pipe. Steel

pipes are furnished in random lengths but usually are about 20 feet long. Both ends of each length of standard-strength pipe are threaded and one coupling is furnished on each pipe length. The ends of extra-strong and double-extra-strong pipe are usually unthreaded unless ordered threaded. Couplings have to be ordered separately.

TABLE 27.—EXTRA-STRONG PIPE, FULL STANDARD WEIGHT—BLACK AND GALVANIZED

(All Weights and Dimensions are Nominal)

Size	Diameters		Thickness	Weight per foot, plain ends
	External	Internal		
1/8	0.405	0.215	0.095	0.314
1/4	0.540	0.302	0.119	0.535
3/8	0.675	0.423	0.126	0.738
1/2	0.840	0.546	0.147	1.087
3/4	1.050	0.742	0.154	1.473
1	1.315	0.957	0.179	2.171
1 1/4	1.660	1.278	0.191	2.996
1 1/2	1.900	1.500	0.200	3.631
2	2.375	1.939	0.218	5.022
2 1/2	2.875	2.323	0.276	7.661
3	3.500	2.900	0.300	10.252
3 1/2	4.000	3.364	0.318	12.505
4	4.500	3.826	0.337	14.983
4 1/2	5.000	4.290	0.355	17.611
5	5.563	4.813	0.375	20.778
6	6.625	5.761	0.432	28.573
7	7.625	6.625	0.500	38.048
8	8.625	7.625	0.500	43.388
9	9.625	8.625	0.500	48.728
10	10.750	9.750	0.500	54.735
11	11.750	10.750	0.500	60.075
12	12.750	11.750	0.500	65.415

The standard-strength pipe is ample in every way for ordinary steam, water, and gas purposes up to a pressure of 250 pounds, though extra-strong pipe is preferable for feed-water lines and boiler blow-off pipes. For pressures over 250 pounds extra-strong pipe should be used.

Fittings.—The fittings for threaded steel and wrought-iron pipe are numerous and are either cast- or malleable-iron shapes provided with a threaded connection to receive the end of each pipe. The fittings may be cast-iron shapes equipped with flanges properly drilled with bolt holes so as to make a bolted connection to the pipes. In the latter case, the ends of each length of pipe must be provided with flanges securely screwed on.

For water and gas lines, all steel pipes 3½ inches and less in diameter should have threaded fittings and all lines 4 inches and

Double-extra-strong Pipe, Full Standard Weight—Black and Galvanized

(All Weights and Dimensions are Nominal)

Size	Diameters		Thickness	Weight per foot, plain ends
	External	Internal		
½	0.840	0.252	0.294	1.714
¾	1.050	0.434	0.308	2.440
1	1.315	0.599	0.358	3.659
1¼	1.660	0.896	0.382	5.214
1½	1.900	1.100	0.400	6.408
2	2.375	1.503	0.436	9.029
2½	2.875	1.771	0.552	13.695
3	3.500	2.300	0.600	18.583
3½	4.000	2.728	0.636	22.850
4	4.500	3.152	0.674	27.541
4½	5.000	3.580	0.710	32.530
5	5.563	4.063	0.750	38.552
6	6.625	4.897	0.864	53.160
7	7.625	5.875	0.875	63.079
8	8.625	6.875	0.875	72.424

over should have flanged fittings. In steam power-plant work threaded fittings may be used for all pipes 2 inches in diameter and under; all pipes over 2 inches should have flanged fittings. This is desirable on account of the difficulty usually experienced in making up tight joints with large threaded fittings.

Threaded Fittings.—Threaded fittings may be either of cast or malleable iron. Cast-iron fittings may be obtained in two grades, the standard-weight fitting and the extra-heavy fitting. The standard-weight fittings may be obtained in either beaded shapes or in banded form. The banded and beaded ends reinforce the fittings against splitting strains occasioned when screwing them on the pipes as well as against pressures in the pipes.

Pressures as far as the strength of pipe fittings are concerned are usually classified as low pressure when less than 25 pounds per square inch; standard pressure when between 25 and 125 pounds; medium between 125 and 175; and extra heavy for pressures from 175 to 250 pounds. As far as this book is concerned, and the same is standard practice in the average power plant, two classes of pressures will be considered: standard to 125 and extra heavy to 250. Standard-weight, cast-iron screwed fittings may be used for pressures up to 125 pounds per square inch.

Extra-heavy, cast-iron screwed fittings may be used for pressures up to 250 pounds. The extra-heavy fittings are furnished only in the banded shape. The extra-heavy fittings are heavier

than the standard fittings, all dimensions being increased. The difference is most noticeable in the length of the fittings and width of bands.

Malleable-iron fittings may be obtained in plain patterns or beaded or banded. The plain fitting may be used for low pressures; the beaded or banded shapes may be used for pressures up to 150 pounds per square inch. Malleable-iron fittings are strong and dependable for steam pressures up to 150 pounds per square inch and are widely used on water pipes and gas lines. Malleable fitt ngs are commonly specified by municipal ordinances for water and gas pipes in buildings. They should preferably be galvanized to prevent rusting and to seal any small pores in the iron and thus prevent sweating and leakage from porous metal.

Practically, the only wrought-iron fitting in common use is the ordinary pipe coupling. On all steam lines conveying saturated steam, it is customary to use cast-iron fittings, either standard weight or extra heavy. Cast-steel fittings are used for superheated steam at heavy pressures.

Changes of direction in a line of steel pipes are affected by 90-, 45-, or 22½-degree elbows. Intersecting lines of pipes are connected by crosses, tees, and 45-degree branch tees. Pipes in the same line may be connected by couplings, unions, flanges, and reducers. Small pipes may be connected by right and left couplings instead of unions. Pipes of different diameters may be connected by reducing couplings or elbows or by using a bushing.

Unions.—Unions are useful for connecting pipes, and facilitate in disconnecting them without taking the entire line of pipe apart. Box or nut unions having threaded connections are to be recommended for pipe up to 2 inches in diameter, for larger sizes flange unions are preferable. Box unions usually have ground joints of iron to brass or brass to brass; gaskets are not used with them. Unions that are made entirely of iron require gaskets. Unions may be had in standard and extra-heavy weights.

Flanged Fittings.—Flanged fittings are preferable for all piping 4 inches and over in diameter as well as for all high-pressure systems and other important work. The flanges of fittings are not drilled unless specified when ordered. Standard drillings for fittings are in multiples of four, straddling the vertical and horizontal center lines. The connections are bolted with bolts hav-

ing square heads and hexagonal nuts. Flanged fittings are made in what are known as standard-weight and extra-heavy fittings.

Standard-weight, cast-iron fittings are intended for pressures up to 125 pounds per square inch and have plain-surfaced faces. The joint is usually made with a full-face gasket. Extra-heavy cast-iron fittings are intended for pressures up to 250 pounds and are provided with a raised surface $\frac{1}{16}$ inch high inside of the bolt holes. The joints are made with a ring gasket.

Companion Flanges.—Where threaded steel pipes are installed with flanged connections, the joints between lengths of pipe and between pipes and fittings or valves are made by cast-iron

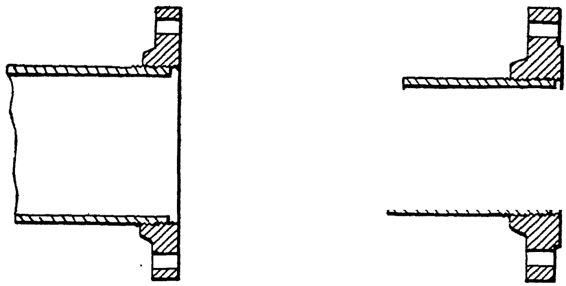


Fig. 361.—Standard cast-iron screwed companion flange.

Fig. 362.—Extra-heavy cast-iron screwed companion flange.

companion flanges screwed on the threaded ends of each length of pipe (see Figs. 361 and 362). Cast-iron companion flanges are made in standard and extra-heavy weights. Like the flanges on flanged fittings, the standard-weight companion flange is made with a plain-surfaced face and is suitable for pressures up to 125 pounds. The extra-heavy companion flange is made with a face having a raised surface and is intended for use with pressures up to 250 pounds.

Loose Ring Joint.—Companion flanges are used on pipes up to 12 inches in diameter. Pipes larger than 12 inches should be made with loose ring type joints. This type of joint is made with a loose ring flange, as indicated in Figs. 363 and 364. The end of the pipe is turned outward to form a flange, as shown. This flange forms the true joint and engages the gasket. In making joints with red lead, the surface of this flange only needs covering with the lead. The loose ring type joint makes very easy erection work in the field as the ring flanges are loose and free to turn and, consequently, are easily brought together and

bolted. The loose flanges may be made of any suitable material such as cast iron, cast steel, rolled steel, wrought iron, or forged steel.

Sheet-iron Pipe.—Pipes of sheet iron are suitable for purposes requiring large capacity. In industrial work they are used largely for conducting air from fans or blowers at a pressure of a few pounds. They are usually hung from the floors or the roof supports.

Sheet-iron pipe is usually made of galvanized iron or preferably from one of the rust-resisting irons that are sold under various trade names. Rust-resisting iron possesses this property

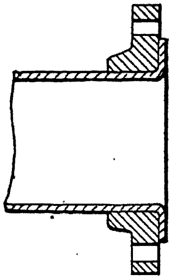


FIG. 363.—Loose ring joint.

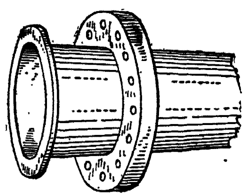


FIG. 364.—Loose ring joint.

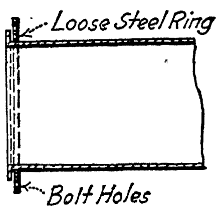


FIG. 365.—Joint for sheet-iron pipe.

entirely through its freedom from impurities. It has the appearance of ordinary sheet iron. The thickness of the sheet iron used varies with the diameter of the pipe and should run from about 22 gage for pipe 10 inches in diameter to greater thicknesses for larger sizes. The joints between the sheets of iron are lapped and should be both soldered and riveted. The rivets should be spaced about 1 to 1½ inches on centers.

Figure 365 shows a typical detail for a joint between lengths of sheet-iron pipe. As shown, the metal of the pipe is turned outward at a right angle to form a flange at each end of the pipe. The two adjacent flanges are held together by loose rings of cast iron or steel properly drilled with holes for bolts. The sheet-metal flanges are drawn into contact by the loose ring flanges through which the bolts pass.

The loose ring flanges as well as the sheet-iron flanges are not faced and, for this reason, gaskets are necessary. Thick gaskets should be used either of cardboard or of asbestos sheeting or the

joint may be packed with wet asbestos and then drawn up tight with the bolts.

Changes of direction and branching of pipes are accomplished by sheet-iron fittings made similar to the pipe. The fittings are usually rather expensive as each sheet of metal forming them has to be specially laid out and a great deal of time is consumed in making them.

Gaskets.—Gaskets are used to make a tight impermeable joint between flanges of pipes, fittings, and valves. They are flat rings of rubber, metal, or other material. Gasket material is supplied in large sheets. The gaskets, however, may be purchased already cut to size. Gaskets may be cut to cover the entire area of the flanges. They are then known as full-face gaskets. They may be cut to lie entirely inside the bolt circle, when they are known as ring gaskets. The ring gasket is the better type, as the pressure from the bolts is concentrated over a smaller area and inequalities along the outer rim of the flange cannot exert any influence to destroy the effectiveness of the gasket (Fig. 366). The full-face gasket is easier to place concentric with the pipe than the ring gasket.

FIG. 366.—*a*. Full-face gasket. *b*. Ring gasket.

Thick gaskets are suitable for light pressures and for use with flanges that are not smoothly faced. Thin gaskets are necessary for high pressures and for use between flanges that are smoothly faced. The thinner gasket gives the tighter joint because the smallest possible packing area is exposed to pressure.

The sheets of gasket material may be cut to fit a flange by placing a sheet of the material against the flange and striking it with a hammer along the edges of the bolt holes and the edge of the flange until the material is cut through. This gives an exact duplicate of the face of the flange. The rounded face of a pein hammer will be found useful in cutting out the bolt holes. A bolt hole at the top of the gasket should be cut first and a bolt inserted to hold the material steady while the other bolt holes are cut. As soon as a second hole is cut out, another bolt should be

inserted to hold the gasket in line. After all the bolt holes are cut, the gasket is cut around the rim of the flange.

For pipes conveying water, some form of rubber gasket will be found suitable. Canvas-insertion rubber gaskets are ordinarily used for low-pressure lines; for heavier pressures up to 160 pounds wire-insertion rubber gaskets 1/16 inch thick will give good service. Large pipes with heavy pressures may have gaskets of corrugated metal.

Saturated steam lines with pressures up to 125 pounds may have wire-insertion rubber gaskets 1/16 inch thick. High-pressure steam lines over 125 pounds and standard-pressure lines as well are commonly provided with asbestos gaskets of material which is 1/16 inch thick and made especially for the purpose. Gaskets between flanges in steam lines are inserted dry, without any jointing compound. Corrugated-metal gaskets may be employed for the larger sizes of piping when conveying high-pressure steam. Asbestos gaskets are in general use, as asbestos is a mineral substance not effected by heat and is neutral to most chemical actions; for that reason it may be used where the pipes convey high-pressure steam or chemical solutions. It may be had in thicknesses of 1/64, 1/32, and 1/16 inch. Where large pipes convey air or hot gases asbestos board or loose asbestos may be used.

Gaskets for gas pipes may be of cardboard, sheet asbestos, or loose asbestos. Usually, it is sufficient to join smoothly faced flanges with a red-lead coating without a gasket of any sort.

The joints between flanges on oil lines may be filled with a paper gasket either dry or covered with shellac.

Air pipes are usually large and any thick cheap gasket of such materials as cardboard, asbestos board, or loose asbestos will answer the purpose. Other gasket materials frequently used are paper, canvas, lead, copper, or lead wire, and corrugated metals in combination with other substances. Pipes below ground may be provided with gaskets of canvas dipped in red lead.

Valves.—Valves in water and saturated steam lines 1½ inches in diameter and under should be all bronze and have screwed connections. All valves 2 inches and over should have iron bodies. All valves 2½ inches and over installed in steam lines should have flanged connections and should preferably be of gate or angle pattern unless in the position of a throttle valve. Valves should have discs and seats of bronze, and gate valves over 2 inches should have a rising stem and yoke. Bronze

valves in sizes over $1\frac{1}{2}$ inches may be used in boiler-feed lines. Valves with brass bodies may be obtained. They are in common use in cheap work, but they are not as strong as the valves with bronze bodies.

A valve should be placed as near as possible to the pipe from which the supply is checked and should be within reach of a man

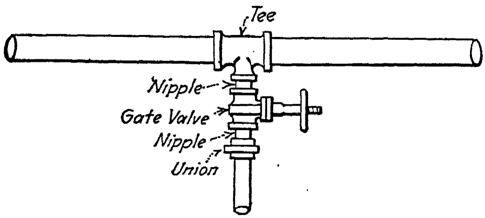


FIG. 367.—Branch connection.

standing on the floor. Ordinarily, each valve will have a union adjacent in such a position that the valve will be left to shut off the supply when the pipe is disconnected, as shown in Fig. 367.

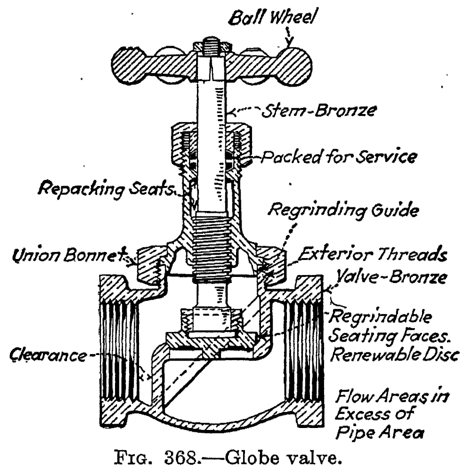


FIG. 368.—Globe valve.

This arrangement with screwed fittings will bring a valve, a union, and two nipples together. For the sake of appearance, the valves should be placed so that the valve stems are not pointed in different directions. It is generally preferable to place all the stems horizontal as they are easier to manipulate and present a better appearance when in that position.

Valves in steam lines should be located so as not to form water pockets with the condensation. For this reason, globe

valves should always be placed with stems horizontal (Fig. 368). In this connection it may be added that the great majority of valves, inserted in the steam lines of a power plant, function as shut-off valves and should therefore be gate valves which provide a clear passage for the flow of steam when open (see Fig. 369).

Globe Valve.—Globe valves have spherical bodies with the valve opening at right angles to the cross-section of the pipe, so that the flow is compelled to make two right-angle turns while passing through the valve (see Fig. 368). Globe valves are commonly used as throttle valves and possess the advantage that they may be closely regulated and provide a sure throttle, which closes absolutely tight. Another advantage is that the valve seats are easily reground when worn by constant use.

Objections to their use are that the valve opening is seldom equal to the full area of the corresponding pipe, and that the shape of the valve opening provides a serious resistance to the flow. On account of the shape of a globe valve, there is danger of a water pocket being formed in steam lines where the valve has not been placed with the stem in a horizontal position. When a line of water pipe is drained, a globe valve may hold the pipe half full of water in similar manner. A globe valve in a steam or a water line should be turned so that the pressure is taken under the disc and not on top of it.

Gate Valves.—Gate valves have full-size straightaway openings with seats of bronze or soft material (Fig. 369). They possess the advantages that the shape of the opening presents little resistance to flow, that they are strong, and that they are suitable for pipe lines of large size. The disadvantages of gate valves are that they are not suitable for use as throttle valves as they cannot be closely regulated. When opened and closed frequently, the valve seats become worn and are not easily repaired. When in this worn condition they do not close tightly; the discs become loose and permit leakage to occur.

Gate valves may be had with inside or outside screws. All gate valves 2 inches and over should have outside screws. An outside screw is preferable as the rising stem indicates whether the valve is open or shut. The stem of a large valve, when out, may be protected by inclosing it in a piece of steel pipe of suitable size, closed by a cap at one end.

Angle Valves.—Angle valves are a modified type of globe valve and may be used where a valve is desired in the position usually

occupied by an elbow fitting. They serve as a means of controlling the flow and, at the same time, provide a change in the direction of the flow. They are suitable for both large-and small-sized lines and may be used for throttle valves without presenting any great resistance to the flow of steam or water (Fig. 370). The valve seats are of brass or soft material and, like the globe

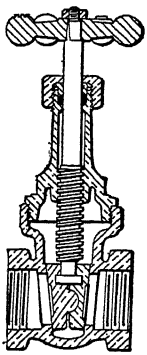


FIG. 369.—Gate valve.

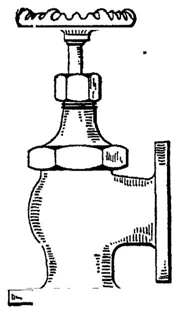


FIG. 370.—Angle valve.

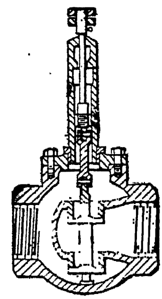


FIG. 371. Pressure reducing valve.

valves, they should be turned so that the pressure comes under the seat.

Pressure-reducing Valves.—Figure 371 shows a cross-section through the body of a typical pressure-reducing valve. They are employed where it is desired to furnish steam to a machine at a constant pressure lower than the pressure in the supply line. As may be seen from an inspection of the figure, the steam in the supply line operates against the pressure of a spring, and opens the valve orifice so that sufficient steam is allowed to pass. This brings the pressure on the far side of the valve to the desired intensity.

Back-pressure Valve.—Figure 372 shows a cross-section through the body of a back-pressure valve. The most usual position for a back-pressure valve is in an exhaust pipe to control the release of steam into the open air. This type of valve is used principally in connection with feed-water heaters or where heating systems are furnished with exhaust steam. It is employed to maintain a constant pressure on the system and to prevent the steam from exhausting freely into the atmosphere. It is so designed that it

may be adjusted to the desired pressure and prevent any greater pressure from occurring in the piping system.

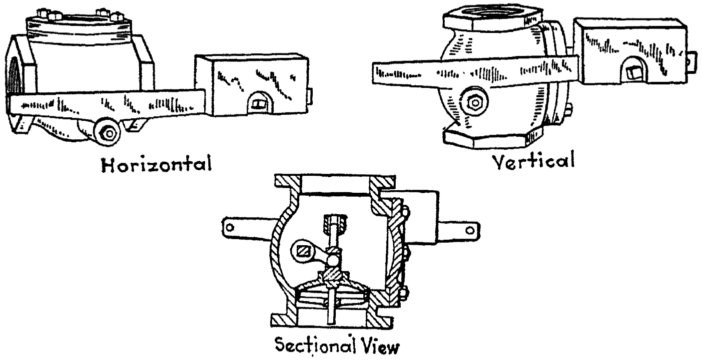


FIG. 372.—Back-pressure valve.

Check Valves.—Figure 373 shows sections through a swing check valve and a lift check valve. Check valves are used to prevent a flow in a direction opposite to that desired and are

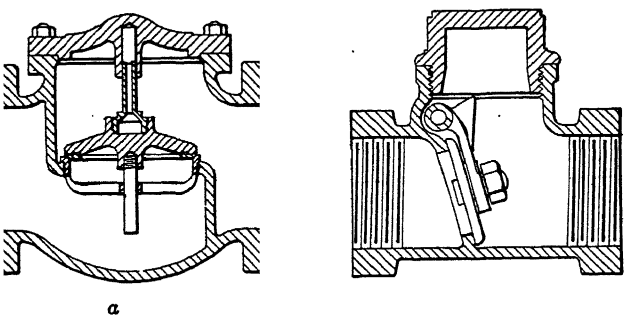


FIG. 373.—*a*. Lift check valve. *b*. Swing check valve.

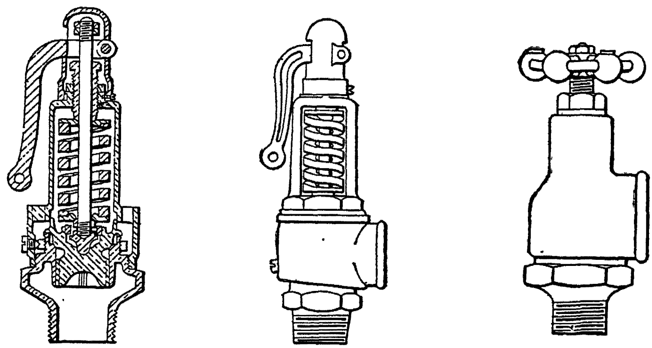
automatic in operation. As may be seen the swing check valve has a full-sized, straight-away opening and presents little resistance to flow. The lift check valve has an opening of such shape that it presents a resistance to flow similar to that occasioned by a globe valve.

The most usual employment for a check valve is in connection with the suction line of a pump. Its position in the suction pipe should be at the extreme lower end so as to hold all of the priming water in the suction pipe at all times. A check valve in pipes under pressure may prove a dangerous arrangement unless a

relief valve is installed in connection with it, in such a way as to release the pressure when it becomes too strong.

Relief Valve.—A relief valve is a safety valve (see Fig. 374). Relief valves are in common use with steam boilers and pumps to release a fluid or gas when a fixed pressure is exceeded. A safety valve on a boiler permits steam to escape when the pressure exceeds the desired amount. The steam is allowed to exhaust freely into the air.

A relief valve should be provided at the discharge side of each pump that is pumping against pressure, in the discharge line



Pop safety valve

Relief valve for liquids

FIG. 374.—Relief valve.

between the pump and the valve in that line. The relief valve should be installed so that it will discharge either into the open air or into an open pipe leading back to the source of supply. The rule generally followed as to the correct size of relief valve to use, in any case, is to have a valve of about one-half the pipe size. Relief valves up to 2 inches in size should have bronze bodies. Valves over that size should have iron bodies. A relief valve should always be used with regulators on steam pumps in case the latter should fail to function properly.

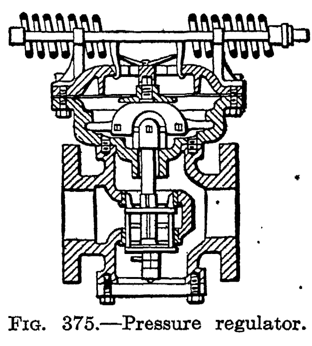


FIG. 375.—Pressure regulator.

Pressure Regulator.—A pressure regulator is placed on a steam-supply line to a machine to regulate the amount of steam being admitted to the machine. It is most commonly used in con-

nection with pumps supplying water or oil at a desired pressure. One side of the regulator is connected to the pump discharge by small piping. As the pressure in the pump discharge line rises or falls, the regulator automatically decreases or increases the quantity of steam admitted to the cylinders. The valve in a regulator is operated by the pressure of the water or other fluid on a spring or a diaphragm.

Steam Separators.—A steam separator should be placed on the steam-supply pipe leading to each important machine (see Fig. 376). The particular purpose for which a separator is intended is to insure dry steam for the cylinder of the engine or machine which it serves. It is so constructed that the steam in passing through it impinges against baffles inside the separator and deposits any entrained moisture. The condensation should be led through the opening in the bottom of the separator to a steam trap the size of which is in accordance with the drain pipe leading from the separator. The separator should always be placed as near the machine as possible. While separators are recommended on steam-supply lines to all engines and large pumps, they are not necessary in connection with the small reciprocating pumps commonly used for pumping boiler feed water and the like.

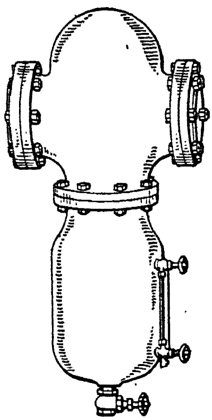


FIG. 376.—Steam separator.

Steam Trap.—Figure 377 shows a section through a steam trap. A steam trap automatically ejects the condensation as

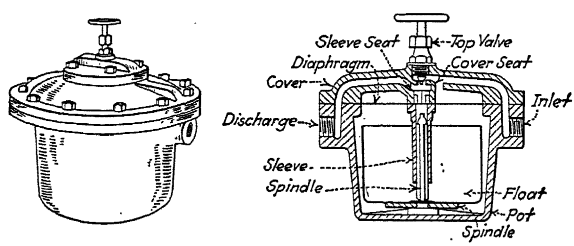


FIG. 377.—Steam trap.

rapidly as it is accumulated, without loss of steam All main steam lines should be drained by drip pipes located at the end

most distant from the boiler. All condensation in these pipes should be led to steam traps. All drips draining steam separators or main steam lines should be trapped. All heating apparatus where the condensation is not piped directly back to the boiler should be trapped, particularly any apparatus below the water line of the boiler.

The steam trap should be placed below the level of the lower opening of any apparatus it is to drain and in a position where it will be easily accessible for cleaning. Sizes of steam traps are rated by the size of the inlet opening.

In connecting the trap, a union and a globe valve should be placed on the inlet side and a gate valve on the outlet. All traps should be bypassed so that they can be taken out for repairs. If a trap is to discharge above the level of the discharge opening, it is necessary to have a check valve in the discharge line. No check valve is necessary where a trap discharges freely below the discharge opening.

PIPE INSTALLATION

Inspection.—Preliminary to the work of installation, all cast-iron pipes, fittings, and valves should be inspected for defects such as cracks and broken parts. The piping plans or order list should be gone over carefully and each individual valve, fitting, and pipe length should be checked off to make certain that no material is missing.

Underground.—Pipes laid underground should be buried deep enough below the surface to be safe from freezing. This will usually require a depth of at least 3 to 4 feet. While the frost may extend into the ground for short periods to greater depths, the water, steam, or other substance flowing through the pipe will usually have a temperature much above freezing and will serve to diminish the effect of frost in the earth immediately surrounding the pipe.

Pipes for conveying water over long distances usually follow the undulations of the ground. Steam lines ordinarily do not extend for long distances and run often in pipe galleries of concrete or are boxed in with plank. A steam pipe installed underground should be laid inside another pipe. The steam pipe should be surrounded with insulation which in turn should be covered with a waterproof covering impregnated with asphalt. When run through pipe galleries, they should be blocked up clear from the

bottom so as to be above any water coming into the gallery during wet weather. This is important in the case of steam pipes which are often covered with insulating covering, as the latter is easily destroyed by contact with water. In any case, all steam pipes should be laid with a slight grade so that any condensation will drain off in the direction of the flow of steam. Provision should always be made for draining off this condensation by a drip pipe supplemented by a steam trap where necessary. Gas pipes and other pipes which are likely to have deposits occurring in them, while laid to follow the main undulations of the ground, at the same time should be arranged to drain toward drip pots inserted in the pipe line at all low points.

Steel Pipe Underground.—In laying threaded steel pipe underground, very few tools are necessary. A pair of pipe wrenches and one or two open-jaw wrenches will be needed, if bolted connections exist. Two pipe wrenches are usually necessary, one wrench being needed to turn the pipe being laid, the other being needed to hold the pipe previously laid against the strain occasioned by the other wrench. As steel pipes laid in the ground are usually the smaller sizes, no particular provision need be made in the way of apparatus to lower the pipe into the trench.

Care should be exercised to lay the pipe to the correct elevation at all points. In the case of steam pipes where a grade is necessary to carry away the water of condensation, it is important that the grade be maintained at a continuous slope so that no pockets of water can be formed at the low points. The same attention should be given to avoid the formation of air pockets at the high points in suction lines to pumps.

In laying pipes in trenches, it is almost impossible to prevent a certain amount of earth from getting into the pipes and fittings. All earthy matter should be removed as far as possible from the interiors of the pipes before they are joined. Foreign matter, such as sand, chips, dust, and pieces of cotton waste, if allowed to remain in the pipes, will eventually lodge in the valves and fittings and cause trouble. For this reason, all pipe lines before being completely coupled up should be blown out thoroughly.

When bolted flange connections are employed, the pipes should be turned so that the bolt holes straddle the vertical center line. This detail should be attended to, where flanged valves are to be installed, so that the valves when bolted in place will occupy a vertical position. While the valves will not be visible below

ground, they are more easily incased in valve boxes when vertical. They are more accessible for manipulation from the surface as well as presenting a more workman-like appearance than they would if they were set out of plumb.

Expansion of Pipe.—Steel pipe expands and contracts with changes in temperature. The coefficient of expansion for steel is 0.0000065. This figure is usually committed to memory as "five zeros sixty-five." The expansion that will take place for any difference in temperature and for any length of pipe is found by multiplying the coefficient by the difference in temperature expressed in degrees, and also by the length. Expansion in a pipe line must be provided for by installing an expansion joint or by arranging the fittings so that a fitting can turn in its threads and permit movement, or by providing loops of bent pipe. As an example of expansion in pipe, it may be noted by measurement of an actual test that an empty pipe 100 feet long will expand 2 inches when filled with steam at 100 pounds pressure.

Bell-and-spigot Pipe Underground.—Bell-and-spigot pipe are usually conveyed from the cars by truck and unloaded along the length of the trench. Fittings and valves should be unloaded at the points where they are to be installed, as any unnecessary handling is expensive and delays the progress of the work. Large valves should be handled carefully to avoid breaking them. They should be unloaded by sliding them on heavy inclined skids placed against the platform of the truck. Fittings and pipe do not require such care. The fittings unless very large may be thrown off the truck on soft ground. The pipe should be passed endwise off the truck to the ground. When unloading on frozen ground or pavements both the pipe as well as the fittings should be unloaded carefully.

It is immaterial, as affecting the pipelaying, in what direction the pipelaying progresses. It is well, however, to arrange so that the calking is done against the resistance of the pipes already laid. Bell-and-spigot pipe when of small size can be lowered into the trench by hand. The larger pipes may be handled by trench tripods set up over the trench and provided with chain blocks for lowering the pipe into place (see Fig. 378).

A trench tripod, such as shown in Fig. 378, is of simple construction and can be easily made. The legs are made of 4-by-6 timbers held together by an iron bolt which acts as a pivot as well as a support for the long shackle from which the tackle or chain

block is suspended. A 1- or 1¼-inch bolt may be used for the pivot, and the shackle may be made from similar stock. The bolt may extend 6 inches to 1 foot beyond the timbers on each side and be provided with pipe collars which will act as washers. This

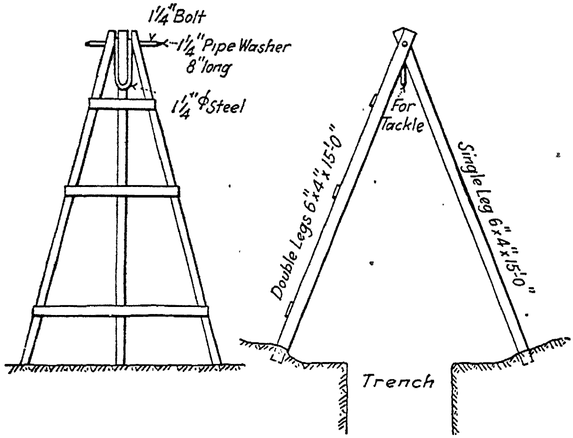


FIG. 378.—Trench tripod.

extension of the bolt will provide a means for the fastening of slings and other rigging to the top of the tripod when necessary.

The bottom of the trench should be graded to give the pipe an even bearing. Heavy pipes should be laid on short pieces of timber laid crosswise in the bottom of the trench. The blocks may be set at the proper grade and in that way greatly assist in the work of pipelaying. With the smaller sizes of pipe the usual procedure is to trim the bottom of the trench roughly to grade and then to bed the pipe either by shoveling earth in under it or digging more away in spots, as the case may be.

The side and bottom of the trench should be dug out at the positions to be occupied by the joints to provide space for proper calking of the joint. A space of 18 inches or more is usually required for the manipulation of the calking iron and hammer. A number of bell holes should be dug in advance so that several pipe lengths may be laid and the joints made at one time.

The pipe to be laid may then be brought to the side of the trench opposite the position it is to occupy and is then rolled out over the center of the trench on a pair of heavy planks thrown across the top of the trench. The tripod is then brought for-

ward and set up over the center of the pipe. The easiest way of erecting a tripod is to place it flat on the ground at right angles to the trench with the double-legged portion underneath and, from this position, up ending it, at the same time carrying the single leg across to the opposite side of the trench.

The pipe should then be lifted in a sling by means of the tripod to clear the planks; the latter are then removed and the pipe is lowered into position in the bottom of the trench. If the tripod has been placed exactly in the correct position, the pipe can be readily inserted into the bell; usually, however, it will be necessary to change the position of the sling somewhat to guide the spigot.

The pipe may be moved endways in either direction by changing the position of the sling toward one end. As the weight of the pipe is taken on the chain block, the pipe will move into the bell or out of it according to the position of the sling. Care should be taken to shove each spigot home in the bell.

Where necessary the positions of bends and tees and similar fittings may be determined in advance, and where such positions are fixed and cannot be spaced an equal number of pipe lengths apart, a length of pipe may be cut to piece out the required distance.

All valves on pipe lines buried in the ground should be boxed in. If the pipe line is an important and permanent one, the valves should be placed in valve chambers with brick or concrete walls. When building such concrete or brick-valve chambers, the walls should be so located that space is provided for making up any joints near them. In the case of bell-and-spigot pipe, the bells should preferably be turned away from the walls so that the joints can be calked at any time. With flanged joints, the flanges should clear the masonry a sufficient distance to permit the removal or insertion of the bolts. A valve box should always be built without a bottom so that any water seeping into it will drain away quickly.

It is often required, on important work, that pipe lines which are to be buried in the ground should be tested to a pressure of a specified number of pounds to guard against the presence of defective pipes or leaky joints. The portion of the pipe line to be tested may be shut off by valves or the ends of the pipe may be closed by other means. The pipes are then filled with water, a hole having previously been tapped in the top of one of the

pipes for the connection of a force pump. An ordinary small force pump, worked by hand, is then connected to the pipes and is operated until the required pressure is attained.

Bell-and-spigot Joints.—Bell-and-spigot joints are usually made by filling the space between the spigot and the inside of the bell with a packing of jute yarn and a filling of molten lead. The lead is poured into the space and calked firmly with calking irons. Metal alloys are on the market which may be merely poured into the joints and do not require calking. This saves the time and expense of calking as well as the inconvenience of digging bell holes in the sides and bottom of the trench. Bell-and-spigot pipe are frequently laid with cement joints in gas company work. A cement joint is very strong and, in cases of breaks, it will usually be the body of the pipe which is found to have failed rather than the joint.

The secret in laying bell-and-spigot pipe quickly, lies in introducing the spigot into the bell so that there is a uniform space all around between the spigot and the inside of the bell. To do this quickly, a wedge may be fashioned from an old calking iron and used for centering the spigot in the bell. If the wedge is placed exactly under the center of the pipe, a blow or two with a hammer will bring the spigot to a true center and the joint is ready for yarning. Many experienced pipelayers, however, introduce a length of yarn into the bell with the spigot and use one or two cold chisels for centering the pipes.

Lead Joints.—A length of jute yarn long enough to go around the pipe and lap a few inches is placed around the spigot end of the pipe and the spigot is entered into the bell. Care should be taken not to use any yarn that is wet, as the effect with molten lead is likely to be disastrous. The yarn before being inserted should be twisted to make it firm. It is then pushed back into the bell with the yarning iron until it strikes the curve of the spigot (Fig. 379). As it is pushed back against the curve of the spigot, the yarn is forced upward on the curve and becomes wedged against the inside surface of the bell. The yarn is then compacted and calked with the yarning tool until it is solid. Additional yarns are then calked into the bell until the bell is filled with yarn to the depth specified. This will usually be half the depth of the bell. The yarn filling prevents the molten lead from running past the end of the spigot into the pipe and holds the spigot in the center of the bell.

The remainder of the joint, about 2 inches, is then filled with molten lead and the latter is calked firmly into place. To guide the molten lead into the joint, a roll made of fire clay with a yarn center or a "jointer" made of woven asbestos may be used (Fig. 380). The usual practice is to use a jointer. The asbestos

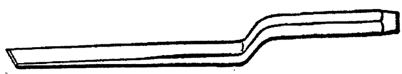


FIG. 379.—Yarning tool.

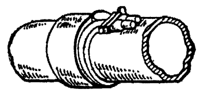


FIG. 380.—Asbestos lead joint runner.

jointer should be soaked thoroughly in water for some time before using it. The jointer is placed around the pipe against the end of the bell and both ends are turned out along the top of the pipe to form a channel and pouring hole for the lead. The two ends are held together by an iron clamp.

The lead should be melted ½ hour or so before the joints are poured. Care should be taken to bring the lead to the right heat. If the lead is too cold, it will not flow easily and will make a poor joint. If the fire is too hot, the lead will be burned. This will not do any particular harm except that of wasting some lead. The molten lead may be tested for proper temperature by inserting the end of a stick of wood into it. If sufficiently heated, the lead will char the end of the stick but the wood will not take fire. If too hot, the wood will immediately catch fire.

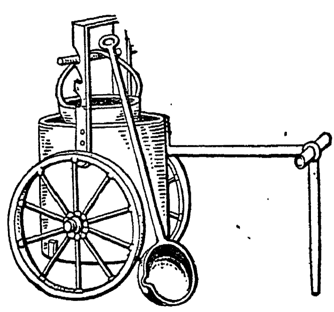


FIG. 381.—Lead-melting furnace.

The surface of the molten lead should be a golden color. A red color is a sign that the lead is too hot. The lead is melted in a furnace, as shown in Fig. 381. The fire may be made with wood, coal, or any other fuel.

The melted lead is carried to the joint in an iron ladle and poured into the channel provided by the jointer. Several ladlefuls are usually required to make a joint between large pipes. When the lead in the joint has solidified the jointer is removed and the lead filling is calked. The ladle should be thoroughly heated over the furnace before dipping into the lead. If any

lead appears to stick to the dipper, it may be accepted that the lead is too cold to use.

A set of calking tools consists of a 3- or 4-pound hammer, a cold chisel, a yarning tool, and several calking irons of different thicknesses. The operation of calking is started by cutting the lead free from the barrel of the pipe with the cold chisel

Fig. 382.—Calking tools.

around the entire perimeter. The thinnest calking iron is then used in the groove cut by the cold chisel, working the entire distance around the pipe (Fig. 382). The next thicker calking iron is then used in similar fashion, and so on, each time using a larger iron and progressing upward to the tool which completely fills the joint space. There will always be a certain amount of lead left at the jointer opening. This may be cut off at the start but may be more safely left in place until the last of the calking. The molten lead in the joint when cooling shrinks away from the inside surface of the bell and this method of calking is employed

Table 28.—Pounds of Lead and Jute per Joint

Diameter of pipe, inches	Pounds of lead per joint	Pounds of jute per joint
3	6	0.18
4	7½	0.21
6	10¼	0.31
8	13¼	0.44
10	16	0.53
12	19	0.61
14	22	0.81
16	30	0.94
18	34	1.00
20	37	1.25
24	44	1.50
30	54	2.00
36	65	3.00

to force the lead outward against the bell. The quantity of lead and jute required per joint is given in Table 28.

Disconnecting a Bell-and-spigot Joint.—The quickest and easiest way of disconnecting a lead joint is to melt the lead with an acetylene torch. When an acetylene torch is not at hand and

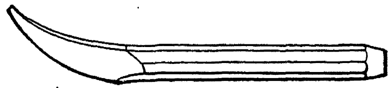


FIG. 383.—Picking chisel.

in many cases, as in gas company work, where it is not practical or convenient to use a torch, the joint filling has to be dug out. The picking chisel is used for this purpose (Fig. 383). A cement joint can only be disconnected by digging out the cement and yarn with a picking chisel or a similar tool.

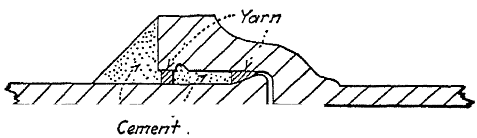


FIG. 384.—Cement joint.

Cement Joints.—Cement joints in bell-and-spigot pipe are made by filling the joint space with neat cement and two calkings of jute yarn (Fig. 384). The spigot is centered in the bell in the same manner as for a lead joint and a length of yarn is calked into the bottom of the joint space. One length of yarn is sufficient, as it is only necessary to insert enough yarn to hold the

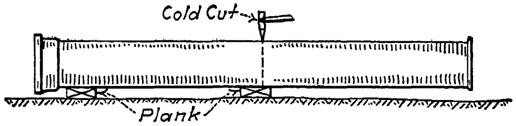


FIG. 385.—Cutting bell and spigot pipe.

spigot in a central position and to prevent the cement from being pushed past the spigot into the pipe. The joint is then rammed nearly full of neat cement moistened with water. Sufficient depth of bell should be reserved to admit another layer of yarn. This additional calking of yarn should be as thick as possible and should be calked hard against the cement filling. The purpose of this second yarn is to force the cement solidly into the bell and to hold it in place until it has hardened.

After the second layer of yarn is calked, more cement is added over the yarn, completely filling the remainder of the bell. The surface of the cement is then finished with a smooth, sloping surface, as shown in Fig. 384.

Cutting Bell-and-spigot Pipe.—Frequently, a length of bell-and spigot pipe must be cut to a shorter length (Fig. 385). This may be done by cutting a circle entirely around the pipe with a cold cut and a sledge. When a piece is to be cut from a standard length of pipe, the exact distance between the shoulders of the bells to be occupied by the pipe should be measured. The actual length of the pipe cut should be about ½ inch shorter than this dimension. When a piece of pipe has to be cut to fit between two bells which are fixed in position, care should be taken not to cut the pipe too short. If too much space is left between the spigot and the bottom of the bell, the yarn is apt to be pushed through past the end of the pipe.

To mark the pipe for cutting, a piece of board with a square end is procured and a nail is driven into it at a distance from the end equal to the length of pipe to be cut. A circle is marked around the pipe with this device by measuring from the spigot. The pipe is rolled slowly, the nail being held against the end of the spigot. The pipe is marked at the square end of the board.

To cut the pipe, it should be placed on two timbers or heavy planks laid level on the ground (Fig. 385). One of the timbers should be placed directly under the circle marking the position of the cut. The portion of pipe to be cut off is allowed to project unsupported at the end. A groove is cut in the pipe, following the mark carefully, by a cold cut and sledge, the pipe being rolled slowly as the cutting proceeds around the pipe. The cutting and the revolving of the pipe continues until the pipe separates along the line of the cut. Cast-iron pipes of small diameter may be cut with the wheeled pipe cutters such as are usually used for cutting steel pipes.

FLANGED CAST-IRON PIPE

Making Up Flanged Joints.—The operation of making up a flanged joint is simple and requires but few tools. Suitable open-jawed wrenches are necessary to turn up the bolts. In tightening the bolts each nut at first should be brought to a snug bearing, then working around the circle again, each nut should be given

a part turn repeating the process until all the bolts are made tight. Several drift pins and drift bars 2 or 3 feet long will also be found useful in bringing the holes into line as the pipe is guided into place.

In connecting one line of intersecting pipes to another, it will often be found that the position of the holes in the flanges of the pipe will not bear the same relation to a vertical line as the holes in the flanges of the fitting. When this discrepancy is very slight, the 1/8-inch play in the bolt holes will permit the bolts to be inserted. If the discrepancy is too great to be overcome in this manner, as a last resort, bolts of smaller diameter may be used. To allow plenty of play around the bolts, it is the custom of some manufacturers to cast their fittings and valves with slotted holes, the long axis of the hole being made to coincide with the center line of the bolt circle.

Red-lead Joints.—Flanged joints of cast-iron pipe may be made tight by a coating of red lead or similar preparation applied to the face of the flanges or by a gasket of suitable material inserted between them.

Red lead is supplied either in powdered form or ground in oil. The powder should be prepared for application to the joints by mixing it with boiled linseed oil until it has a proper consistency for spreading on the flanges. Often, some white lead is added to the mixture but, on heavy flanged pipework, this does not seem necessary.

The red lead and oil may be most easily applied to the flanges with a small flat pointing trowel. Only one of the flanges coming into contact is coated with the red lead, and it is preferable that it be applied only to that portion of the face of the flange which is inside the bolt holes and not to the whole surface of the flange. The linseed oil in the mixture becomes oxidized in time, takes a set, and becomes hard and impermeable.

Manganese Joints.—A flange joint may be made up in a similar manner with manganese dioxide and white lead. Manganese dioxide is a black powder. White lead is sold ground in oil. A sufficient quantity of manganese dioxide is mixed with white lead to make a thick paste. The mixture is spread out on a flat surface and worked thoroughly until it has the consistency of a thin putty. It is applied to the surfaces of the flanges about 1/8 inch thick. In a short time it takes a set and becomes very hard.

Flanged joints made up with gaskets are discussed in the sections devoted to gaskets and in the section dealing with steel pipe with threaded connections.

STEEL PIPE ABOVE GROUND

Laying Out.—When laying out pipework for cutting of pipe and installation of valves and fittings, the dimensions that should be considered are outlined in Fig. 386. In the figure, the dimensions are shown as extending from centers of fittings to centers of valves and the like. With this system of laying out the work, allowances may be readily made for the lengths of standard fittings, extra-heavy fittings, or long-radius bends as the case may be. Likewise allowance can be made for the difference in over-

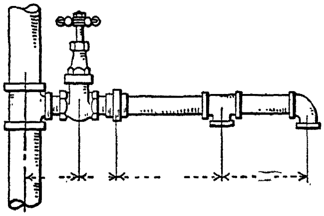


Fig. 386.—Laying out pipe work.

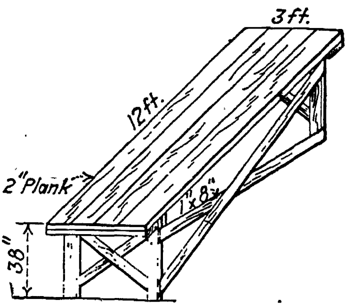


Fig. 387.—Pipe fitters' bench.

all dimensions of valves of the various manufacturers as well as for the dimensions of valves for standard and extra-heavy pressures.

In selecting pieces of pipe to be cut and threaded, care should be exercised to prevent any split pipe from getting into the work. A split pipe is occasioned by faulty welding during manufacture and may usually be discovered by inspection of the pipe. The length of pipe to be cut should be brought to the pipe bench and placed in the pipe vise for cutting.

The pipe-fitters' table or pipe bench should be about 3 feet in width and 3 feet high and about 12 feet long (Fig. 387). It should be of stout construction. The top should be made of 2-inch planks. The legs may be made of plank or of lumber of substantial cross-section. All legs should be cross-braced both crosswise and longitudinally. The bench should be equipped with a hinged pipe vise for the smaller sizes of pipe and a chain

vise to hold the larger sizes. Both of these vises should be bolted to the ends of the table, preferably, at opposite ends. A combination pipe vise or a machine vise with plain jaws may be bolted to one side of the table. The table should always be wide enough to furnish room so that the wrenches, oil cans, and miscellaneous tools used in pipework may be permitted to remain on the bench without interfering with the work being done on the pipes.

Cutting Steel Pipes.—Steel pipes of ordinary sizes are customarily cut to length by hand with a wheel pipe cutter. Each cutter may be employed for cutting pipe within a fixed range of sizes, one size being capable of cutting pipe varying in size from ½ to 2 inches, another from 1½ to 3 inches, and so on. Usually four or five cutters of different sizes are necessary. Extra wheels should always be kept on hand as the cutter wheels become dull and chipped with use. The tool should be placed over the pipe, the wheels tightened to bear against the pipe and, with each turn or two around the pipe as the grip of the wheels loosen, the handle should be twisted to tighten it and the process continued until the pipe parts along the cut.

As the use of the three-wheel cutter leaves a burr on the inside of the pipe, it is always necessary to use a reamer on the cut ends to remove the burr. On account of this disadvantage of the cutter, it is customary to cut all small pipe, under ¾ inches, with a hacksaw, as the saw cuts clean and does not leave any burr to decrease the area of the pipe and to offer resistance to the flow. Hacksaws with pistol grips should be procured for this work as the plain straight handle is uncomfortable to use for any length of time. A cutter with one wheel and two rollers will not form so large a burr as that with three wheels, as the cutting wheel is thinner. The condition of pipe ends when cut with a three-wheel cutter and with a one-wheel cutter are represented in Fig. 388. As will be seen, the ends should be reamed out with a reaming tool to remove the burr on the inside. The burr on the outside of a pipe cut with a three-wheel cutter

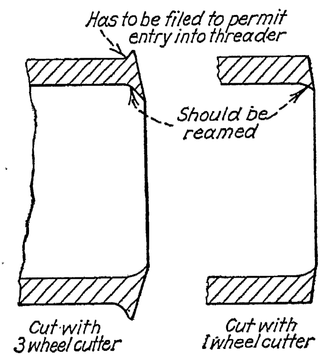


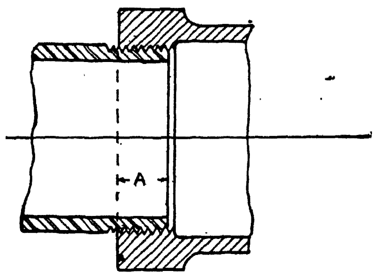
FIG. 388.—Pipe ends cut with wheeled cutters.

has to be removed with a file, before it can be inserted into the collar of the threading machine.

Threading.—To thread a pipe, it should be placed in the pipe vise and securely clamped. The dies in the stock are adjusted to the size of pipe to be threaded and the threading machine is then placed over the end of the pipe and rotated. It is necessary to lubricate the dies plentifully as the cutting of the threads proceeds. Cutting oil is used for this purpose. Lard oil is the best cutting oil but it is expensive and a cheaper cutting oil is usually employed. The advantage of a cutting oil over a lubricating oil is that there is less tearing of threads by the threading dies. Linseed oil is a very good cutting oil.

TABLE 29.—LENGTH OF THREAD ON PIPE THAT WILL MAKE A TIGHT JOINT WHEN SCREWED INTO VALVES AND FITTINGS

(Threaded to Briggs Standard)



Size, inches	Dimension A, inches	Size, inches	Dimension A, inches
1/8	1/4	3 1/2	7/8
1/4	1/4	4	1
3/8	5/16	4 1/2	1
1/2	3/8	5	1 1/8
3/4	7/16	6	1 1/8
1	1/2	7	1 1/4
1 1/4	9/16	8	1 3/8
1 1/2	5/8	9	1 3/8
2	11/16	10	1 1/2
2 1/2	3/4	12	1 5/8
3	7/8		

Several sizes of stocks and dies are necessary for an ordinary job of pipe fitting. One set of stock and dies may be obtained to thread pipe from ¼ to 1¼ inches in diameter, a second 1½ to 2 inches, and a third up to 6 or 8 inches and so on. The stocks for cutting the threads on the smaller sizes may be of a type which is revolved continuously around the pipe. Pipe-threading machines for threading pipes over 1¼ inches should always be

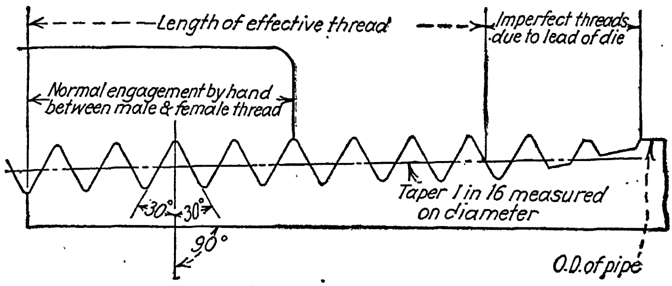


Fig. 389.—American standard pipe thread.

equipped with a ratchet, as considerable force is required to cut the threads.

The length of thread on pipe that is required to make a tight joint is given in Table 29.

The threads on fittings bought from different companies are not always exactly the same, although intended to conform to the

Table 30.—Number of Threads per Inch American Standard Pipe Thread

Diameter of Pipe, Inches	Number of Threads per Linear Inch
⅛	27
¼	18
⅜	18
½	14
¾	14
1′	11½
1¼	11½
1½	11½
2	11½
2½ and over	8

same standard. For that reason, after a thread has been run over once with the pipe threader, a fitting should be screwed on the threads lightly and any change necessary in the setting of the dies should be made.

A diagram showing the American Standard pipe thread is presented in Fig. 389. The following important features may be noted: The threads are cut with a taper of 1 on 16. There are a number of threads that are cut to a full depth and there are several threads that are imperfect. These imperfect threads are cut by the lead of the die. The manner in which a die starts a thread is shown in Fig. 390. The number of threads per inch for different sizes of pipe is given in Table 30.

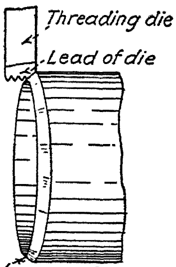


FIG. 390.—Start of pipe thread.

It is not necessary to have many threads to make a tight joint. If a cast-iron fitting intended for a standard pressure of 125 or 250 pounds be inspected, it may be noted how few threads are provided. There will be, usually, five threads in fittings under 2 inches in size and seven or eight threads in fittings larger than 2 inches.

The dies should be set up so that the threads that are cut on the pipe will go hand tight in a fitting with three or four turns. The fitting should make up tight with three hand turns and three or four turns with a wrench. The number of turns indicates the precision of threading. Ordinarily, eight threads are sufficient to make a tight joint. If more or less than three or four turns are required to make the fitting hand tight, a leaky joint may be anticipated. There should be, preferably, three threads showing outside the fitting. These are the three imperfect threads shown in Fig. 389. If more than three threads show, the threading is too long. If less than three threads show, the threading is too short. If the thread is cut too long, there will be a number of threads without taper and the pipe may be screwed so far into an elbow that the end may come into contact with the interior curve of the fitting before the tapered threads can make up tight. If the thread is cut too short or loose, the full depth threads at the end of the fitting will ride up on the shallow imperfect threads on the pipe and a wedging action takes place that tends to spread the fitting and loosen the connection. Both long and short threads are the cause of leaking joints.

In screwing a fitting on a pipe with a wrench, the fitting will lose its chill or feel warm to the hand as it is made tight.

When inspecting the workmanship in pipework, the number of threads showing outside the fitting will give an indication of the care exercised in installing the piping. In making a pipe railing, tight joints are not essential and it is possible to thread the pipe with a short loose thread, so that the pipe can be screwed into the fitting with no threads showing. Most pipe threaders are so constructed that two parts of the machine come in contact when the dies have cut a full length thread. Dies are so regulated that a standard diameter is maintained unless the parts become worn or displaced.

Threaded Joints.—More care is necessary to insure tightness in making up a threaded joint, perhaps, than is necessary with any other type of joint. Steam piping put together with only ordinary attention to workmanship may show a number of small leaks when steam is first turned into the pipes. While many of the smaller leaks will stop of themselves by choking with deposits, pipe which has been carefully installed should be free from any such leakages.

Careful workmanship seems to be the important principle behind good pipework. The dies employed for threading the pipe play an important part in forming tight joints and should cut clean sharp threads. The threads should be cut with sharp dies and the pipes should be carefully screwed home in the fittings. With clean-cut threads, pipe joints may be made tight without applying any jointing preparation.

It is important also to clean the threads and to free them from any chips and turnings left by the threading tools as well as to free them from any sand, earth, or other gritty substances. Care in screwing up the joints also must be exercised, if tight work is to be attained. The joints should be screwed up slowly so that the metal of the threads is not forced. If threaded joints are screwed up rapidly, heat is generated immediately by the friction and the threads swell, bind, and become worn by the force required to screw the pipe into the fitting.

Threaded joints should be given a coating of some jointing preparation. The coating should be applied to the innermost portion of the fitting threads as well as to the pipe threads to insure lubrication the entire length of the threads. A jointing compound acts as a filler between the threads and also as a lubricant.

For pipe threads on steam lines, a manufactured graphite compound made expressly for the purpose is best. It serves equally well for water and gas pipes. A jointing preparation for permanent joints may be made by mixing graphite with linseed oil. For joints that will have to be taken apart, a mixture of graphite and cylinder oil will be found suitable as it does not become hard.

When threaded connections have to be made with pipe of large diameter, 6 inches and over, thread-clogging mixtures like red lead will not furnish sufficient lubrication and will often prevent a connection from being screwed tight. In such cases, graphite and oil, or oil alone will furnish better lubrication and will permit connections between large pipes and fittings to be made more easily.

A mixture of red lead and linseed oil is frequently used as a jointing preparation for water and gas pipes. Red lead and linseed oil is also customarily employed in joining flanged cast-iron pipes in gas company work. The red-lead mixture commonly applied to threaded joints is made by mixing powdered red lead with linseed oil, either raw or boiled, until the mixture has the consistency of a thin paste.

Shellac makes an admirable jointing material for jointing pipe lines conveying oil at ordinary temperatures. Oil which has been heated, however, will leak through any but the most perfect joints. Ordinary jointing preparations or shellac will not hold it back. A mixture of litharge and glycerine is the best joint preparation to use. Joints made up with this preparation can usually only be disconnected by breaking the fittings.

Litharge is a yellowish powder and is similar to red lead in appearance and also chemically. The mixture has a tendency to unite chemically with the metal of the pipes and fittings.

Years ago, when fittings were wrought by hand, it was the custom in making threaded connections, to wind a fiber of flax hemp around the pipe in the base of the threads and to cover the threaded portion with a mixture of red lead and linseed oil. Such crude methods for obtaining tight joints with steel pipe are no longer necessary. With improved tools for cutting threads, it is possible to do away with coarse compounds for filling the threads. The most satisfactory results are now obtained by well-formed threads being brought into contact, metal to metal.

Fittings and Valves.—Threaded fittings as far as possible should be screwed to the ends of the pipes at the pipe bench so that in erecting the pipe, the pipe end may be screwed into the fitting already in place. The pipe should be clamped in the vise and the jointing preparation should be applied to the threaded portion and lightly to the inmost portion of the fitting threads so that the entire length of the threads will be provided with lubrication. The fitting is screwed on the pipe by hand as far as it will go, taking care not to cross the threads. It is then screwed on tightly with a pipe wrench. The pipe wrench should be applied to the. banded portion of the fitting. The wrench should be applied to the banded portion on the end toward the pipe and should not cause too great a strain as it is likely to crack the fitting. The fitting should be looked over always after being made on the pipe to guard against a cracked fitting being installed in the work. If plugs are to be used in any tees, they should be put in place while the fitting is at the pipe bench.

Small valves may be made up on the pipes in the same manner as the fittings, taking care always not to crack them in screwing them on. In the case of valves, the wrench should be applied to the hexagonal end toward the pipe. Heavy valves can be screwed on after the pipe has been erected. The work can usually be most conveniently performed from a platform or staging.

Companion Flanges.—In preparing steel pipes for equipment with companion flanges, they have to be cut and threaded. The pipe should be cut to a length which is ½ inch short of the distance between faces of flanges. After the pipe has been cut and threaded, it should be placed in the chain vise and the flanges should be screwed on as far as they will go. A plentiful supply of jointing compound should be spread on the threads in advance as the pipes which are usually made up with companion flanges are not small in size and a certain amount of force is needed to screw the flanges on.

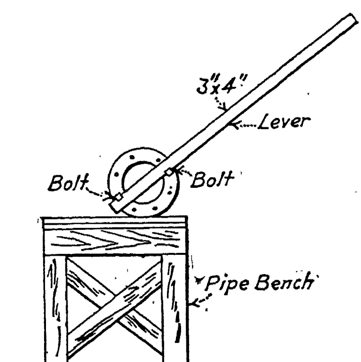


Fig. 391.—Screwing on a companion

The flanges cannot be screwed on the whole length of thread by hand, and they are not readily rotated by wrenches. The customary procedure is to place two bolts in the flange holes, as shown in Fig. 391, and with a piece of 2-by-4 or 3-by-4 lumber used as a lever, the flange is rotated. As the flange can only be rotated a slight distance before the lever touches the ground, it is necessary to move the two bolts to new positions with each manipulation of the lever.

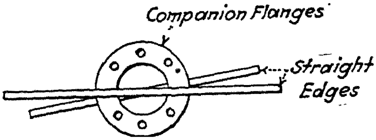


FIG. 392.—Lining up holes panion flanges.

It is essential that the bolt holes in the flanges at each end of the pipe should line up. Probably, the easiest way of accomplishing this is to place a stick or straightedge across the flange at each end of the pipe in line with the bolt holes, as shown in Fig. 392. By sighting from one stick to the other and rotating one of the flanges, the two sticks may be brought into line.

Bending Pipe.—Almost every pipe installation will require a certain number of bent pipes to provide easy changes in direction of flow and to assist in providing for expansion. Some pipes may be bent cold; in other cases, it is necessary to heat the pipe in a fire before bending it. All small pipes, if the radius of bend is long enough, may be bent cold; with a shorter radius, it is necessary to heat them. Pipes of small diameter may be bent cold by placing them between chocks nailed to the top of the pipe bench (Fig. 393).

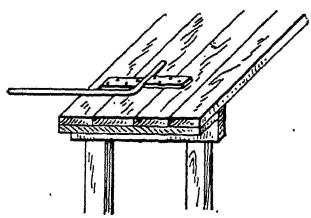


FIG. 393.—Bending small pipe.

In bending the pipe, a sufficient portion of straight pipe should be preserved at the ends so that the pipe can be threaded. Where bends come close to the ends of a pipe, it is good practice to make the bends as a part of a long pipe and to cut it to the correct dimensions after bending. All pipes, unless the radius of the bend is very easy, should be filled with sand before they are bent, whether the pipes are to be heated or not, to prevent them from kinking.

The minimum radius recommended by general practice for pipe bends is five times the nominal diameter of the pipe. The operation of bending a pipe in the field where the pipe has to be

heated in a fire is tedious and uncertain and, if there are many bends to be made or the pipes are large or the bends are sharp, it will be found best to have them bent in a local pipe-bending shop. It is the general practice, where pipes are bent to short radius, to use extra-heavy pipes on account of the thinning of the outside wall of the pipe during bending. There are several shops, however, that recommend the use of standard-strength pipe.

Large pipes should be bent while heated to a red heat. It is best to prepare a steel or cast-iron bending table for the bending work. A cast-iron bending table can be purchased from supply companies. The top of a bending table should be perforated with holes so that steel pins can be inserted in them and the pipe bent into any desired shape.

All pipes should be filled with sand to prevent kinking. All sand should be heated before it is put in the pipe, and the sand should always be kept dry. Both ends of the pipe should be plugged to retain the heat and to prevent the sand from moving during the bending process. A pipe may be heated for bending in a fire 6 or 7 feet long, or it can be heated in a riveting forge. With a long fire one heating will often be sufficient. With a short fire several heatings may be necessary.

The pipe should be heated to a red heat and then bent on the bending table. The operation of bending should proceed slowly. The sand in the pipe slows up the operation of heating, as the sand must be heated as well as the pipe, before the pipe will turn red. When a pipe is being bent, there is always a strong tendency for kinks to form at the end of the red portion. A few drops of water sprinkled on the pipe at these points will stiffen the metal and the bending can be resumed.

Standard-strength pipe can be bent as easily as extra strong pipe and it is much lighter to handle. The work of pipe bending may be considered a specialty, and experienced men should be hired if there is much pipe bending to be done.

ERECTION

Erection.—The methods used in erecting pipe and putting them in place differs with the size of the pipe and their location. When indoors, the pipes may be located overhead along the walls or under the floor and trusses. When out of doors, the pipes similarly may be run along the side of the walls, run as an air line

supported on posts or bents, or suspended in midair from cables. Staging may be necessary in some cases, in others it may not be. Rigging of some sort may be needed with pipes of small diameters, with large heavy pipes, it is usually essential.

Where pipes are run along walls, they may be lifted into place by tackle fastened to planks placed against the walls in an inclined position (Fig. 394) or by tackle fastened to supports overhead. In any case, before arranging for the use of timbers or making any provision for the support of tackle, it is well to examine the existing structure overhead to see if there are any supports there already, which can be used. There is usually some part of a structure from which tackle may be hung.

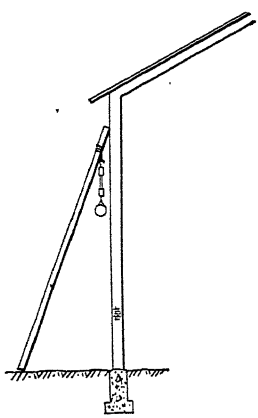


FIG. 394.—Erecting pipe along wall.

Steel pipe lines not over 2 inches in diameter can usually be made up without a scaffold. The pipe can be lifted into place and the joints can be made up by men working on ladders. For pipes with screwed joints over 2 inches in diameter, it is best to erect a staging, particularly at the locations of valves as the latter have considerable weight and are difficult to install unless they have flanged joints. Steam lines intended for high-pressure steam require careful work to prevent leaky joints and, unless the lines are very easy to reach, it will usually prove desirable to put up staging. Large heavy pipes with flanged joints may be erected in similar fashion. For this work planks resting on tall horses will provide a convenient platform from which to work.

Where brackets fastened to the wall are provided for the supports of pipes, it is well if possible, to have them bolted in place before the pipes are erected, so that temporary supports for the piping are not necessary.

A method of supporting a pipe by a bracket bolted to a wall is shown in Fig. 395. It may be laid down as a general principle that it is preferable to hang a pipe from a bracket than to use the bracket as a shelf, as adjustments of grade are more easily made by means of the threaded eyebolt.

Where pipes are to be hung under a floor, it will usually prove best to erect staging. The staging should be constructed of the

heavy two-post type. When the pipes are to be hung from the bottom chord of roof trusses, a needle-beam scaffold will usually prove the most suitable. The needle-beam scaffold should be hung from the truss by rope lashings as explained elsewhere.

There are various types of hangers designed to suspend pipes from beams. When hung from wooden beams, the pipes may be hung in hangers nailed to the side of the beams (Fig. 396). Where hung from steel beams, the hanger should be clamped to the bottom flanges of the beams (Fig. 397). Small steel pipes

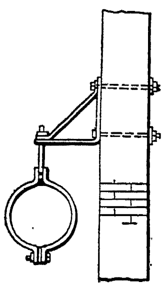


FIG. 395.—Wall bracket.

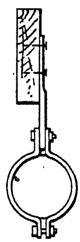


FIG. 396.—Pipe hanger.

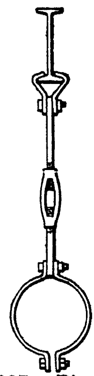


FIG. 397.—Pipe hanger.

when first put in place may be wired to beams or trusses, temporarily, until the permanent hangers can be installed.

Where pipes are to be erected out of doors in the open air, some sort of scaffolding will usually be necessary. If the pipes are run as an air line and are to be supported on top of posts or bents already in place, they may be raised by means of a pole derrick or dutchman. The joints may be made up by men working from ladders. If supports are not in place previous to erecting the pipe, it will be necessary to erect the staging to serve also as a temporary support for the pipe.

The staging, when built for light steel pipe, may be constructed as a two-post structure with the legs made of 3-by-4 timbers and with 2-inch platform planks. Where heavy pipes of large diameter are to be erected, a heavier scaffold is desirable. The legs should be of 4-by-6 timbers or even heavier material. With large heavy pipes, the staging needs to be heavy as well as strong.

For erecting heavy pipe, a scaffold, such as shown in Fig. 398, will be found suitable. There are several features worthy of

notice. The general design is heavy and substantial. The legs of the staging, preferably 4 by 6 lumber or heavier; are carried up beyond the platform and serve to support the longitudinal timber overhead. The latter is an important feature as its purpose is to furnish a support for the tackle by which the pipe is hoisted. This is a very desirable arrangement as the tackle may be supported anywhere along its length. It should be 6 by 6 or larger in cross-section depending on its span and the weight of the pipe. The bents of the staging should be spaced about 14 feet

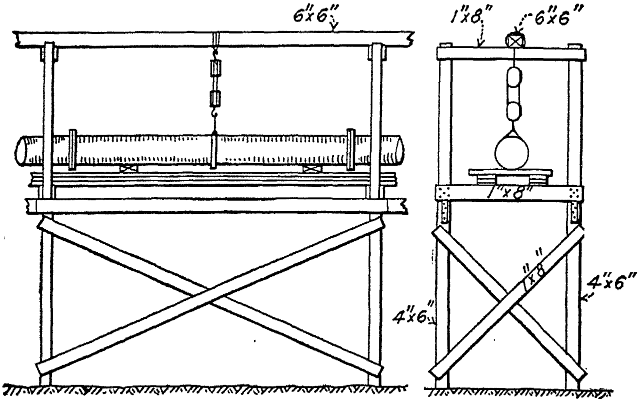


FIG. 398.—Heavy-pipe scaffold.

apart longitudinally to facilitate the handling of standard 12-foot lengths of pipe. The legs should be cross-braced in both directions.

The platform planks should be doubled up or made of extra-heavy plank on account of the long span and to allow them to serve as supports for the pipe. The planks should be placed on either side of the pipe with an open space between through which the pipe may be hoisted. The height of the platform should be fixed so as to be 6 inches to a foot below the bottom of the pipe so that the latter may be supported from the platform without too much blocking being required. The cross-pieces supporting the platform should be nailed fast with five nails and supported by cleats in addition.

PIPE TACKLE

Tackle.—A chain block is particularly well adapted to the work of erecting heavy pipes. While the rate of travel is slow, it can

be readily operated by one man and will sustain the load at any point. A pair or two of small 4-inch all-iron blocks rove with ½-inch rope will prove particularly useful for hoisting small pipes, raising chain blocks, and for a variety of other uses too numerous to mention.

A plentiful supply of small chains should be kept on hand besides a number of rope slings of various sizes. The chains may be equipped with both rings and hooks. It will often pay to have a very short chain not over 2 feet long on hand fitted with round hook at one end and a grab hook at the other.

Alteration Work.—When alterations are made in the steam lines of a plant in active operation, it is usually for the purpose of adding to the number of branch mains or adding new branch pipes to machines. Unless suitable fittings can be found in the existing lines to which connections can be made, it is necessary to cut into a line and insert a tee. This work should be done at a time when it will least interfere with the plant operation and usually is done as speedily as possible, all preparations being made in advance.

Before cutting into the line, the valves controlling the steam supply must be shut. As little work as possible should be left to be done after the steam has been shut off. If the line to be cut into is made of pipe with flanged joints, the flanges at each end of one of the pipes are unbolted and the new tee, valve, and other fittings are put into place. Where flange joints or a union does not exist, it is necessary to cut the barrel of the pipe in two and remove the parts.

There should always be a valve on the branch outlet of the tee to serve as a shut-off valve for the branch line. The valve at that location also serves a useful purpose when cutting into a main, as the operation of the plant can be resumed as soon as the valve is in position and closed. The installation of the remainder of the branch piping may be done without occasioning any further interruption to the plant operation.

POWER-PLANT EQUIPMENT

Equipment.—The same elementary equipment is to be found in all steam plants. All have the steam-generating units of boilers and distribution systems of headers, mains, and branch lines leading to various points. They also have drainage pipes, pumps, and water piping. Feed-water heaters, steam separators,

super-heaters, and other refinements are added with the increasing size and importance of the plant. The boilers are always erected by skilled men sent out by the manufacturers, the boilers being bought at a contract price for boilers and equipment complete and in place. The steam piping and other appurtenances

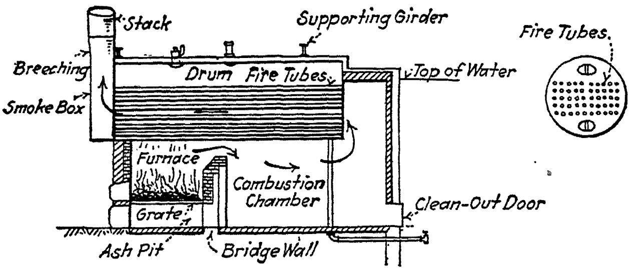


FIG. 399.—Fire-tube boiler or return tubular boiler.

may be contracted to companies doing that sort of work, or they may be installed by men in the employ of the construction force.

Boilers.—The boilers are either of the fire- or water-tube type. Figure 399 shows the general construction of a fire-tube boiler, and Fig. 400 the same for a water-tube boiler. The fire-tube boiler is most commonly found in the smaller plants and is usually of the horizontal type known as a return-tubular boiler. Where

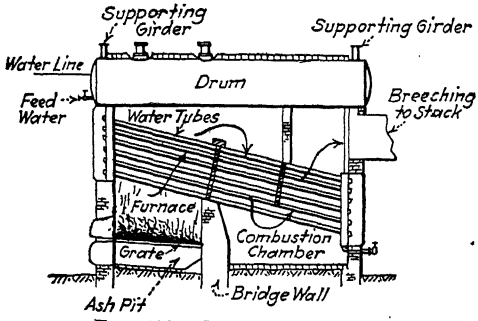


FIG. 400.—Water-tube boiler.

floor space is valuable a vertical fire-tube boiler may be installed.

Water-tube boilers are widely used and are economical in generating steam and possess elements of safety against explosions and facilities for making repairs. Most of the large power plants are served with steam from the water-tube type of boiler. The first cost of the fire-tube boiler is less than the water-tube boiler and it requires less vertical space.

Water-tube boilers are shipped in sections and may be taken into existing buildings through small openings.

As shown in Fig. 399, the fire-tube boiler is so called from the fact that the hot gases from the grate pass through the inside of the boiler tubes on the way to the stack. The tubes are surrounded with water. The water-tube boiler, as shown in Fig 400, is so called from the fact that the tubes are filled with water. The water tubes are surrounded by the hot gases from the grates.

The fire-tube boiler, illustrated in Fig. 399, is known as a return-tubular boiler. The products of combustion going from the grate pass over the bridge wall along the underside of the boiler shell and into the combustion chamber in the rear giving up part of their heat to the boiler shell. The gases then reverse in direction and pass into the boiler tubes at the rear of the boiler returning to the front of the boiler through them and passing through the smoke box, breeching, and stack on the way to the open air. The approximate level of the top of the water in the boiler is indicated in the figure. The space above this line is occupied by the steam.

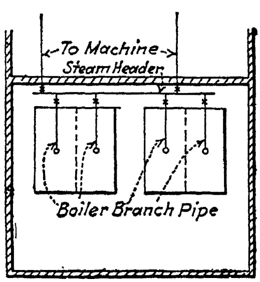


Fig. 401.—Plan of boiler room piping.

In the water-tube boiler, shown in Fig. 400, the hot gases from the grate pass upward around a portion of the tubes. The flow of the hot gases is then controlled by baffles located so that the gases are made to pass among the tubes several times on the way to the breeching and stack.

It should be noticed that the natural position for the stack connection to a return-tubular boiler is at the front of the boiler. In the case of a water-tube boiler, the natural position for the stack connection is at the rear.

Boiler Piping.—The general arrangement of steam pipes at the boiler end of the distribution piping is modified somewhat by the relative positions of the boilers and the machines to which the steam is piped. Figures 401 and 402 show a plan of what might be termed a standard arrangement of boiler-room piping; many others are possible.

The steam generated by a boiler passes through the nozzle attached to the top of the steam drum and enters the piping system through the boiler branch pipes. The steam flows through the

boiler branch pipes into the steam header and thence through the steam mains to the branch pipes which convey the steam to the various machines. The steam having done its work in the various machines may be further utilized by leading it by a system of exhaust steam pipes, either through a feed-water heater or into a heating system; or it may be exhausted into the open air.

Water condensing in pipes is likely to gather in pockets to be carried away at intervals by the steam at a high velocity. Steam travels through the pipes sometimes at a high velocity, often as high as 1 mile per minute. The water in such a case will cause knocking and vibrations in the pipes and will put a severe strain on elbows, valves, and other obstructions, resulting eventually in leaky joints and breaks. For this reason, it is necessary to provide an adequate system of piping to drain away this water as well as that which becomes condensed in the cylinders of engines, pumps, and other machines. This water of condensation is often wasted into outside drainage channels or into sewers. Every pipe carrying such condensation, coming either from a steam pipe or a machine, must drain directly into a steam trap before being wasted, otherwise a free outlet will exist for the steam.

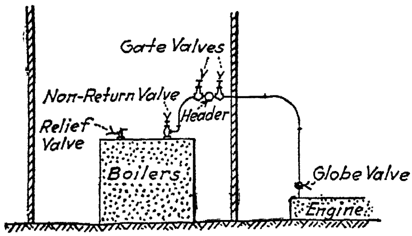


FIG. 402.—General arrangement of power piping.

Systems of piping also are necessary to convey the water supply to pumps, storage tanks, and feed-water heaters, and from any of these to the boilers.

Headers.—The boiler branch pipes from the boiler to the steam header should either connect to the top of the header or be otherwise arranged to insure thorough drainage. Figures 401 and 402 show typical arrangements of piping from boilers to headers. It is general practice to use an automatic non-return valve on each boiler and it is preferably placed directly on the boiler steam nozzle (Fig. 402). An automatic non-return valve is installed on boilers to act as a safety measure when one or more boilers in a battery are shut down and others are in operation. The valve prevents steam in the header from passing back into a boiler that has been shut down. It also can be used

as a simple shut-off valve when desired. There should also be a gate valve on each boiler branch at the main steam header. Figure 403 shows a cross-section through a typical automatic non-return valve.

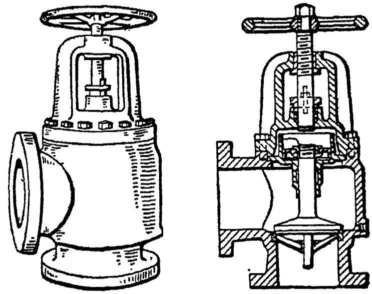


Fig. 403.—Automatic non-return stop valve.

Mains.—The pitch of all pipes should be in the direction of the flow of steam and all steam mains and important branches should end in a drop leg for draining away any condensation. The latter should drain always to a steam trap. Wherever a riser is necessary, a pipe for draining should be connected to the lowest point. Any low points in the system should be similarly drained.

Branch Pipes.—Branch lines should never be taken from the bottom of a main but where possible should be taken from the top. Where the piping is comparatively small, however, it is general practice to connect branch pipes supplying machines

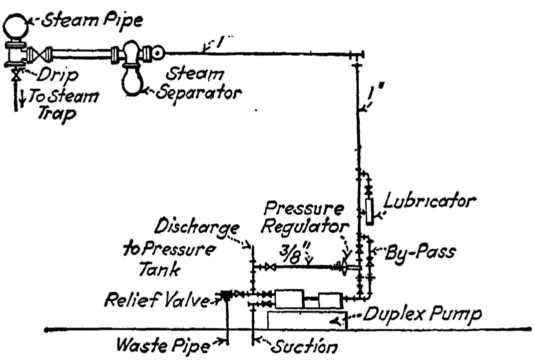


Fig. 404.—Pipe connections to small pump.

with horizontal connections into the side of the larger pipe. Where the branch outlet of the tee is smaller than those on the run of the pipe, the bottom of the smaller pipe will be above the condensation unless there is a large amount of the latter. There are various ways of piping steam from the steam mains to engines and other machines. A typical example is shown in Fig. 402. The modification in each case being influenced by

relative positions and by the necessity of caring for condensation and arranging for drainage.

In each case, lines to machines should be equipped with both a globe and a gate valve. The globe valve is the throttle valve for regulating the supply of steam to the engine and is placed close to the latter. The gate valve is placed close to the supply main and is a stop valve to shut off the supply of steam entirely to the branch pipe leading to the engine.

The pipe supplying a large engine should be provided with a steam separator properly drained. It should have a drip pipe connected to it just above the throttle valve. These provisions for taking care of the condensation may be omitted on small engines and pumps and the condensation may be allowed to pass through the drainage cocks in the machine.

Pump Piping.—A typical example of piping for a small pump is shown in Fig. 404. The positions of valves with unions are shown and are located so as to allow the pump to be disconnected readily from the pipes. A globe valve is provided on the steam-

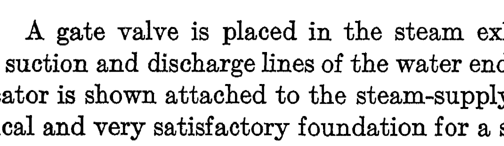


FIG. 405.—Foundation for small pump.

inlet pipe. A gate valve is placed in the steam exhaust pipe, and in the suction and discharge lines of the water end. A sight-feed lubricator is shown attached to the steam-supply line.

A practical and very satisfactory foundation for a small pump is shown in Fig. 405. The pump is elevated above the floor where it may be attended without the discomfort of stooping. The curb around the upper edges of the foundation and the pipe embedded in the concrete take care of the drainage of condensation and oil from the pump.

Exhaust Pipes.—When steam has expanded in the cylinder of an engine, or other machine, part of the steam is condensed into water and is drained off into the drip pipes. The remainder of the steam is allowed to exhaust from the machines while still possessing a great amount of heat. It may still be utilized for heating purposes and for the preliminary heating of the feed water intended for the boilers.

For these purposes, the exhaust steam must be collected into an arrangement of pipes and conveyed to the heating system or the feed-water heater. To this end, a system of exhaust mains must be installed in such a manner that the exhaust from the engines may be led into them. Each exhaust pipe running into the exhaust mains should be led into the top of the main and should be provided with a suitable stop valve close to the main. Any riser pipe running from the engines to the main should be properly drained.

The connections for exhaust steam and water pipes to a feed-water heater are shown in Fig. 406.

Feed-water Heaters.—The preliminary heating of boiler feed water by a feed-water heater results in a saving of fuel, increases

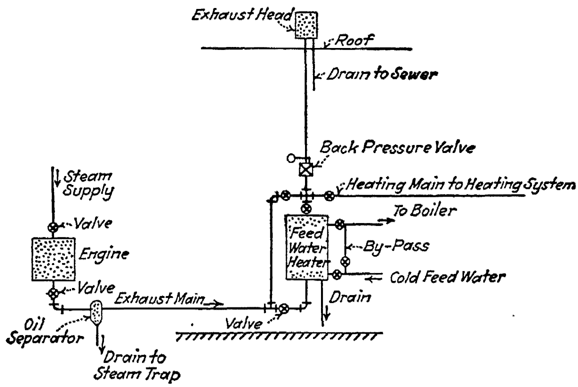


FIG. 406.—Feed-water connections.

the capacity of the boiler, and diminishes the time required to convert the water into steam. There are three kinds of feed-water heaters; closed heaters, open heaters, and economizers. The first two depend upon exhaust steam for their heat; the last utilizes the heat of waste flue gases. In closed heaters, the feed water and the steam do not come in contact with each other. Either the steam passes through tubes surrounded by the water or the water passes through the tubes surrounded by the steam, each being known in either case as a steam- or a water-tube heater.

A closed heater is not suited to waters containing scale-forming matter as the scale will soon clog the tubes. A closed heater is not advisable where the engines work intermittently as the sud-

den heatings and coolings will tend to loosen the tubes. Open heaters are best suited for waters containing scale-forming matters and with engines operated intermittently. Any scale-forming matter may be allowed to precipitate harmlessly in the bottom of the heater and may be easily removed with other sediment.

A pump is necessary in connection with a feed-water heater to introduce the feed water into the boiler as an injector will not inject heated water. There is little loss of steam in operating a pump if the heat in the exhaust from the pump is imparted to the feed water.

STEAM HEATING

A steam heating system with steam having a pressure of less than 10 pounds is called a low-pressure system. The majority of steam-heating systems are of this type. The steam may be provided by low-pressure boilers installed expressly for the purpose, or it may be generated in boilers at a higher pressure and reduced in pressure before admitted to the heating mains. In other instances, it may be possible to use exhaust steam which has been made to run engines and other machines and which still contains sufficient heat to be utilized in the heating system. The first case represents the system of heating used in the ordinary residence or other small building; the other two represent the systems of heating employed in industrial buildings where a power plant is installed for general power purposes.

Heating Boilers.—The heating of residences and small buildings by steam is done by steam generated at very low pressure, 1 pound or more, in what are known as sectional boilers. These boilers are often circular in cross-section and made up of cast-iron sections which when bolted together form the complete boiler. The sections are hollow and when assembled may be filled with water which, surrounding the furnace and flue, is converted into steam.

The boilers used for generating steam in industrial plants are usually of the fire- or water-tube type previously described. As steam is generated in these boilers at pressures of 100 pounds or more, it is necessary to reduce this pressure before admitting the steam to the heating-supply mains. This reduction of pressure is accomplished by a pressure-reducing valve, as shown in Fig. 371.

When steam for heating purposes is derived from exhaust steam, provision must be made to supply steam directly from the boilers in case the supply of exhaust steam fails. In this case, also, a pressure-reducing valve is utilized to lower the pressure.

Steam Heating Pipes.—The steam is led through pipes to the radiators where it condenses and the water of condensation is either led through other return pipes to the boiler or is drained off through the same pipe that conveyed the steam to the radiators. In a two-pipe system with separate supply and return pipes, each radiator will have two connections to the pipe lines. In a one-pipe system, where a single line of pipe acts as a supply pipe as well as a return pipe, only one connection is necessary to each radiator (see Fig. 407). In a one-pipe system, the connection to the radiator is made at the bottom.

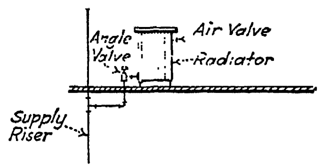


FIG. 407.—Radiator connection, one-pipe system.

Steam Distribution.—Two methods of piping steam for heating purposes in buildings have been developed. They are known as

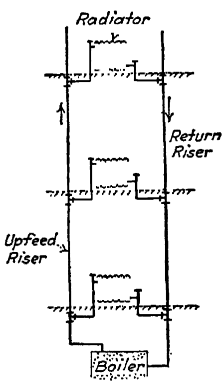


FIG. 408.—Upfeed distribution.

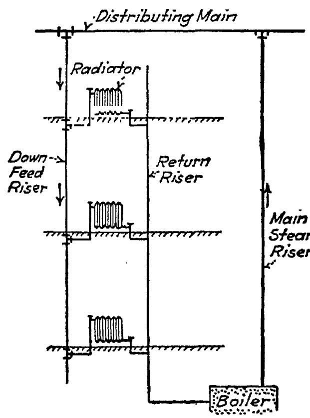


FIG. 409.—Downfeed distribution.

the "upfeed" and the "downfeed" system of piping. Figure 408 indicates the "upfeed" design with double piping. Figure 409 indicates the "downfeed" design in a similar manner.

In the *upfeed* design, the distributing main is carried along the basement ceiling, the supply risers extending upward from it

to the radiators. This design may be used with single piping or with separate supply and return piping. Its use with a single line of pipe for both the steam supply and the condensation return is practically limited to use in structures of three or four stories on account of the large sizes of pipes required. The course of the steam in the upfeed piping is opposite to the course of the condensation and, when one pipe is used for supply and return, this calls for the largest capacities for steam and for condensation in the same regions.

In the *downfeed* piping, the distributing main is carried along under the roof of the building, the supply risers extending downward to the radiators. The distributing main is supplied with steam through a main riser pipe extending upward from the boiler. This arrangement may be used with either single or return piping. It is adapted for use in tall buildings.

STEAM HEATING SYSTEMS

Systems of steam heating for buildings differ in the arrangement of piping, location of valves, air vents, and steam traps. The several systems differ mainly in the methods designed to carry the condensation back to the boiler and to provide vents for any air pockets that may form. Figures 410 to 413 represent the systems of steam heating most commonly employed for heating buildings.

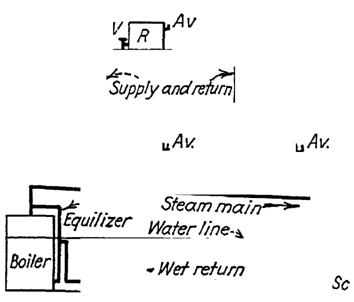


FIG. 410.—Gravity one-pipe system.

Steam is generated in a boiler at a very light pressure and passes from it into steam mains hung under the basement ceiling. The steam passes from the mains into the riser pipes and then into the radiators. As its heat is given to a radiator, the steam condenses into water. The water of condensation then flows back into the boiler through the return pipes.

The return main may be a dry return located above the water line of the boiler, or it may be a wet return located below the water line. A wet return, as its name implies, is filled with water. A wet return is a desirable feature, as the water prevents the passage of steam.

A break in a return line or a high pressure in the boiler might result in the water leaving the boiler, if special arrangements were not made to prevent it. Check valves might be employed but a simpler and more dependable arrangement known as the Hartford connection, shown in the figures, is in general use. As shown in the illustrations, an equalizer pipe at the boiler transmits steam pressure in such a way as to balance the pressure from the water in the boiler. The return line is connected to the equalizer pipe just below the water line. The connection should be preferably made 2 inches below the water line.

The steam main should pitch downward from the boiler in the direction of the steam flow. The end of the main should be drained into the return pipe. Air is heavier than steam and tends to collect at the lower end of the main but cannot pass through the water in a wet return pipe. It is essential, therefore, to provide an air vent at this point.

It is necessary to provide a steam trap at the end of a steam main where it drains into a dry return, to prevent the passage of steam into the return pipe. A sediment chamber, consisting of a pipe nipple with a cap, should be placed at the bottom of all drops and risers, to collect any sediment that may be in the pipes.

Gravity One-pipe System.—In a one-pipe system, the steam supply pipes also act as return pipes. There is, however, a separate steam main and return main. Each radiator has one control valve which must be either entirely open or closed, otherwise the steam and water flowing in opposite directions through the valve will cause the loud noises commonly recognized as water hammer. The pipe connection is always made at the bottom of a radiator, as all condensation has to drain through it. Each radiator must be equipped with an automatic air-venting valve.

Gravity Two-pipe System.—A gravity two-pipe system is designed with separate supply and return pipes. There are two connections to each radiator. The supply pipe may be connected to the top or bottom of the radiator; the return connection must always be made at the bottom to provide drainage for the condensation. There should be two control valves on each radiator. One valve controls the steam supply, the other acts as a shut-off valve on the return connection. Both valves must be either open or closed. If the supply valve is closed and the return valve remains open, there is an opportunity for steam in the return

riser to enter the radiator and cause water hammer. Each radiator should be equipped with an automatic air-venting valve.

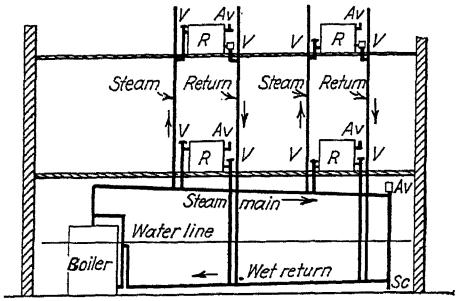


FIG. 411.—Gravity two-pipe system.

Gravity Vapor System.—The outstanding characteristic of a gravity vapor system is that a partial vacuum exists whenever the steam pressure falls to atmospheric pressure or below it. The gravity vapor system is similar to the gravity two-pipe system in many ways excepting that each radiator is equipped with one control valve on the steam supply connection and a steam trap on the outlet to the return pipe. This arrangement permits the steam to be regulated by partially closing the steam valve, without creating objectionable noises. In this arrangement, the steam traps prevent the entrance of steam into the return pipes. The system is designed to operate at a very low boiler pressure and there is small possibility of water backing up into the return system. Air valves are not required on the radiators. There should be a steam trap on the lower end of the steam main and an air-venting valve on the lower end of the return main just before it drops below the water line.

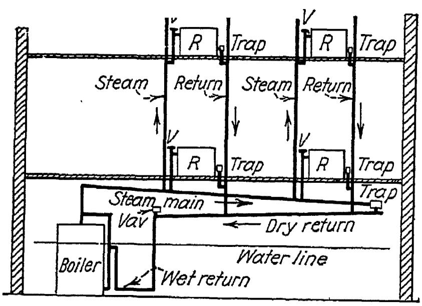


FIG. 412.—Gravity vapor system.

All steam traps should be inspected after the system has been in operation a day or two and all sediment and dirt should be removed from them, as the system will not operate correctly if the traps do not function properly.

Vacuum Pump System.—The vacuum system derives its name from the fact that a pump is employed to draw the condensation from the returns. It is a two-pipe system similar to the vapor system except that a pump draws both condensation water and air from the system. No air vents are needed. Each

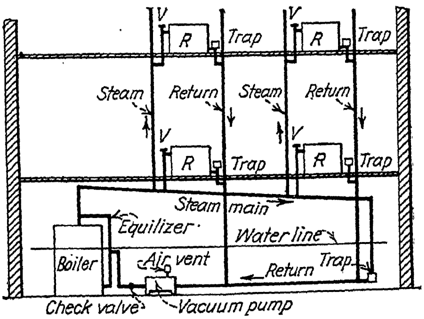


FIG. 413.—Vacuum pump system.

radiator is equipped with one steam control valve on the supply connection and a steam trap on the return connection. There should be a trap on the drop leg between steam main and return. The vacuum pump is usually an electrically driven one of the centrifugal type. A check valve should be installed in the return pipe between the pump and the boiler to prevent any tendency of the water to flow backward from the boiler toward the return main.

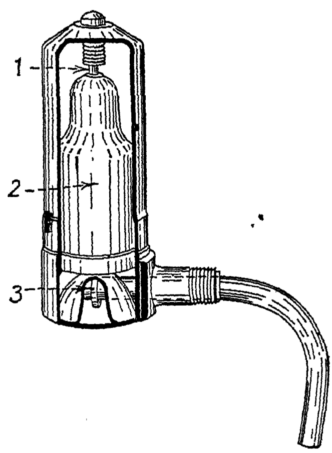


FIG. 414.—Automatic air valve.

Details of Heating Systems.—A typical automatic air-venting radiator valve is shown in Fig. 414. There is a small hole in the top of the valve through which air is vented,, when forced by the pressure of steam. The number 1 indicates the needle point which rises to close the venting hole when the radiator is filled with steam. The number 2 indicates a thermostatic float to the top end of which the needle is secured. Inside the float is a liquid and some air. When a radiator is cold or contains a pocket of air, the air valve will be at the same temperature

and the float will rest in its normal position on its seat, and the venting hole in the top of the valve will be open and release any air at the valve. When hot steam reaches the float, the liquid in it is turned into gas and the float increases in length and forces the needle upward to close the hole and thus shut off the escaping steam.

A typical thermostatic trap, such as is used on the return end of a radiator, is shown in Fig. 415. The operating member of the trap is a U-shaped bourdon tube, charged with a volatile fluid

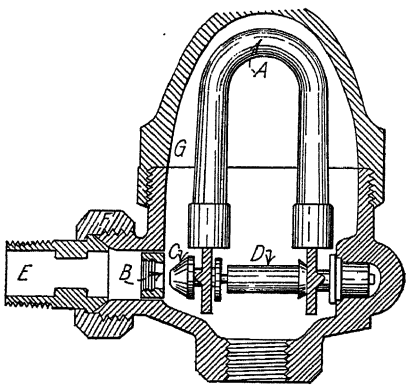


FIG. 415.—Thermostatic steam trap.

and hermetically sealed. When the trap is cool, the tube is in its normal position and the inlet of the trap is open for the entrance of water. As the supply of water is exhausted and steam enters the trap, the tube becomes heated and expands, the two legs of the tube spread outward and close the entrance to the trap, thus preventing the passage of steam.

Radiation below Water Line.—The systems of heating previously described have all been concerned with supplying steam to radiation situated above the water line of the boiler. It is often necessary to supply steam to radiation located below the water line of the boiler and the problem is to take care of the water of condensation.

The illustration (Fig. 416) represents a steam boiler furnishing steam to radiation situated above the water line of the boiler and employing the usual methods of returning condensation to the boiler by gravity. To one side of the boiler, a radiator is shown which is below the water line. In this case, condensation

cannot return by gravity to the boiler and a steam trap is placed on the outlet end of the radiator to drain the condensation from the radiator without loss of steam. It is necessary to either raise the radiator off the floor or lower the trap so that condensation will drain into the trap by gravity. The drainage from the

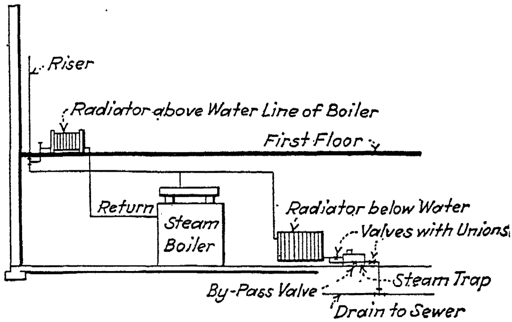


FIG. 416.—Radiation below water line of boiler.

trap can then be wasted. The use of a steam trap in this manner does away with the necessity of locating a radiator near the ceiling in a basement.

Heating with Exhaust Steam.—The exhaust steam issuing from the cylinders of an engine contains a large percentage, 20 to 25 per cent, of water mixed with lubricating oil which has been carried along with it. Before the exhaust steam is permitted to enter the heating main, this water and oil should be removed by leading the steam through a separator.

To keep a steady pressure on the heating system and at the same time to permit surplus steam to escape, a back-pressure valve (see Fig. 372) should be placed on the part of the exhaust main leading to the air. This valve is usually set to operate at a pressure of 5 pounds. Any pressure greater than this causes it to open and release steam through the exhaust head (see Figs. 406 and 417).

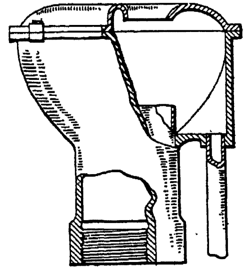


FIG. 417.—Exhaust head.

Where exhaust steam is utilized for heating, it should also be used to warm the feed water by means of a feed-water heater. The installation of a heating system of this character is made very complex in the system of pipes connecting the engine furnishing the exhaust steam and the heating mains by the piping

necessary to serve the feed-water heater and by the various bypasses, valves, and fittings necessary to insure a supply of steam.

The arrangement, shown in Fig. 406, in a general way is common to all exhaust heating systems. The figure shows the engine furnishing the exhaust steam, the exhaust main leading from it to the exhaust head, the back-pressure valve and the connections for the feed-water heater and the heating main taken off under the back-pressure valve. Provision is also made to bypass the feed-water heater when necessary and to cut off the heating main from either the live or exhaust steam.

Radiation.—Figure 407 shows a typical steam radiator with standard pipe connections for an upfeed, one-pipe system. The radiators are preferably situated close to the riser pipes to allow short connections. The connection to the radiator is made by means of a nipple and a special radiator angle valve provided with a threaded union as part of its construction. An air valve is attached to the upper part of the last stand at the opposite end of the radiator.

Figure 418 shows a typical steam radiator with standard pipe connections for a two-pipe system. Two valves are necessary with the two-pipe system of piping and both should be closed or opened at the same time to prevent the water of condensation from backing up into the radiator. With the ordinary steam radiators, these connections are made at the bottom of the radiator, but radiators made like those intended for hot-water heating with top and bottom connections between the stands permit the steam connections in a two-pipe system to be made at the top and the return connection to be made at the bottom of the radiator.

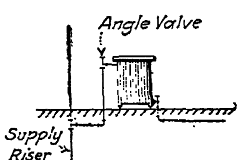


FIG. 418.—Radiator connection, two-pipe system.

Steam heating systems are usually designed in such a way that the water of condensation is returned to the boilers by gravity. Such an arrangement is known as a gravity system or a pressure system. It is the simplest to install and is used extensively. A steam heating system in which a pump is utilized to draw the water of condensation from the radiators is known as a vacuum system.

In proportioning radiation, it may be assumed roughly that a living room or office will require 1 square foot of radiation to

50 cubic feet of volume in each room. For each 100 square feet of radiation, 1 square inch sectional area of piping will be required.

PIPE TAPS

Where pipes of small diameter connect to pipes much larger in size, it may be inconvenient to arrange for special tee fittings for making the connection. In such cases, it is customary to drill a hole in the body of the larger pipe or in a fitting, and to screw the small pipe into the hole after it has been properly threaded.

The drill used in preparing a hole for this purpose should be of a diameter that will provide clearance for the pipe and tap threads and at the same time leave sufficient metal to permit the tap to cut a deep thread. The standard pipe thread used in the United States is the American Briggs standard. Table 31 gives a list of standard pipe taps with the correct diameter of drills and the number of threads to the inch.

TABLE 31.—SIZE OF PIPE TAPS AND DIAMETER OF DRILL FOR PIPE TAP HOLES

(Briggs Standard Threads)

Size of pipe tap, inches	Diameter of drill, inches	Number of threads per inch
1/8	21/64	27
1/4	29/64	18
3/8	19/32	18
1/2	23/32	14
3/4	15/16	14
1	1 3/16	11½
1¼	1 15/32	11½
1½	1 23/32	11½
2	2 3/16	11½
2½	2 11/16	8
3	3 5/16	8

CHAPTER XIII

PAINTING

Paint.—A paint consists of two main portions, a pigment and a vehicle. The term "pigment" is employed to designate the solid portion of the paint. It may be composed of several materials each of which may be termed a pigment. White lead, red lead, white zinc, oxide of iron, graphite, and coloring matters such as chrome yellow are all known as pigments.

Vehicle.—The term "vehicle" is used to designate the liquid portion of the paint. Usually, the vehicle consists mainly of linseed oil with addition of a drier, a thinner, and at times a quantity of varnish.

The vehicle acts as a carrier of the pigment. It distributes the pigment evenly in a thin layer over the surface. It forms a binder for the pigment and adheres tightly to the surface painted. Together with the pigment, the vehicle forms a covering which prevents air, moisture, and gases from coming into contact with the surface on which it is spread.

Pigment.—The pigment protects the vehicle from atmospheric conditions and from abrasion. It increases the thickness of the covering. It prevents attacks of decay in wood and corrosion in metals. It provides coloring and hides the surface.

Purpose.—The scientific application of different combinations of pigments and vehicles to serve the purpose for which each paint is to be used grows to be a subject of considerable depth when all factors are given due consideration.

Paint is applied over wooden surfaces with the purpose of excluding moisture and other agencies tending to induce decay. Another important reason for its use is to beautify with its color and smooth surface the structure over which it is spread.

Paint is used on a steel surface to prevent rusting and to improve its appearance by hiding the surface with a colored coating. In industrial plants where strong fumes or gases are generated, paints are relied upon to protect the steelwork from destructive action.

The nature of the priming coat is of more importance in the satisfactory protection of steel from destructive agencies than the finishing coat. The priming coat should contain a pigment which is naturally a preservative of the steel. Red lead and red oxide of iron are pigments having that property. Carbon and graphite pigments provide excellent finishing coats but should no be used for priming steel as they tend to increase the action of corrosion.

Red lead does not make a good finishing coat, as it fades rapidly when exposed to bright sunlight.

For resisting strong sulphur fumes and gases red oxide of iron will prove a reliable priming-coat pigment. Carbon paints may be used for the finishing coats.

An asphalt paint may be used for protecting steel work but it does not weather well, especially if exposed to the direct sunlight. It is very serviceable when used for underground work.

VEHICLES

Linseed Oil.—The usual and most important vehicle for paints is linseed oil. It is produced by compressing linseed. Linseed oil does not dry like many other oils. It absorbs oxygen from the air and takes a set very much like cement. Raw linseed oil is yellow, straw colored. Raw linseed oil takes two or three days or longer to harden properly, and for this reason it is impractical to use it without treatment. If linseed oil is boiled at a temperature of 200 or 300°, it becomes somewhat thicker and darker in color and gains the property of hardening more quickly than raw oil. Boiled linseed oil hardens in from 12 to 24 hours. Quick hardening is also attained by using raw linseed oil and adding driers to it. The driers cause the oil to oxidize more rapidly.

For painting woodwork either real boiled oil or the raw oil with drier may be used with equally satisfactory results. The general practice is to use the raw oil with driers added. This applies to both outside and inside work. Real boiled linseed oil is desirable as a vehicle for paints which are to be used on metal, plaster, and cement surfaces.

Linseed oil alone and unmixed with pigments may be used as a paint and is often employed for coating ironwork as a preventative of rust and leaves the iron visible for rigid inspection.

Turpentine.—Spirits of turpentine is obtained by the distillation of turpentine which is obtained by tapping the sap of the

yellow pine tree. The residuum remaining after distillation is called rosin. Spirits of turpentine is a volatile oil. The liquid is colorless. A coating of it, when applied to a surface and permitted to dry, leaves a thin, hard, dry varnish. Turpentine has no binding quality. It is a solvent or thinner and only serves to facilitate spreading of the paint. It flattens the gloss of the linseed oil and assists in penetration of porous surfaces. In a general way, less turpentine should be used in metal preservative paints than in paints that are to be applied over wood.

Drier.—Driers consist of various metallic substances combined with an oil or gum and dissolved in turpentine or other solvent. They take up oxygen from the air and impart it to the linseed oil. Driers destroy the elasticity of linseed-oil paints; therefore, the least amount of drier practical should be used.

Pigments.—White lead or carbonate of lead is probably the best known and most used of all paint pigments. It is a pure white powder when fresh and kept without access to air. If exposed, it gradually turns gray due to the action of sulphur gases in the atmosphere. It absorbs linseed oil well and makes a smooth paint. When mixed into paint and exposed to good light it retains its whiteness. It, therefore, makes a good outside paint. If shut off from the light, it has a tendency to turn dark.

Paint made of pure white lead after several months of exposure gradually becomes chalky and washes off with the rain or rubs off. To prevent this action, a quantity of zinc white or other pigment is mixed with it. Too great a portion of zinc white will make the paint brittle.

White lead is supplied to the trade ground in oil.

White-lead paint is very susceptible to sulphur fumes, which, if present in small quantities, tend to turn it yellow. Strong sulphur fumes will turn white-lead paints gray. In the presence of such fumes, sublimated white lead will give better results.

Zinc White.—Zinc white is zinc oxide. As a pigment it is a permanent white. It retains its color under all conditions of exposure. It is not affected by any sulphur gases, or other chemical fumes. It improves the gloss of paint and its working qualities. The highest grade of enamels are made with zinc-white pigment. It is mixed with white-lead paint to prevent chalking.

Red Lead.—Red lead or lead peroxide is a double oxide of lead. It is light orange in color, and is used chiefly as a pigment for the

priming coat on fabricated steel, because its chemical nature tends to prevent corrosion. Since its color fades quickly, it does not make a good finish coat when used alone.

Red lead withstands abrasive wear better than all other pigments, but it is more susceptible to gases and fumes than carbon, oxide of iron, or graphite. Red lead is a heavy pigment and when mixed into paint has a tendency to settle to the bottom of a container and when being applied needs to be stirred up frequently. Red lead is sold in powdered form and ground in oil. The powdered red lead is often added to a white-lead priming paint to quicken and harden the set.

Iron Oxide.—Iron oxide is produced from brown iron ores which are dug out of the earth. It is a very valuable paint pigment. It cannot be excelled as a natural protector of steel against corrosion. It makes the very best priming coat for fabricated steel and is a good finishing paint.

Carbon.—Carbon black makes a very durable paint. A paint made with a pigment of carbon black mixed with iron oxide will last for years.

There are two carbon paints used in the paint industry. These are known as lampblack and carbon black. Lampblack is made by the incomplete combustion of petroleum. Carbon black is made by the incomplete combustion of natural gas.

Carbon black is widely used as a paint pigment. It absorbs linseed oil well and makes a very elastic tough paint. It makes a very superior finishing coat for fabricated steel. It is not suitable for a priming coat as it has no rust-resisting qualities.

Graphite.—Graphite is a form of carbon and is mined from the earth. It is used principally in finish or cover coats on iron or steel. It should not be used as a priming paint. Graphite does not naturally absorb linseed oil and, if mixed alone with the oil, it is likely to separate from it after the paint is applied. If combined with white or red lead or oxide of iron or other pigments, it gives good results.

Asphalt Paint.—Asphalt paint is prepared by dissolving bitumen in petroleum, naptha, or benzine. It is employed as a protection for ironwork against moisture. Asphalt paint does not stand up under weather exposure, especially when exposed to sunlight.

Varnishes.—Varnish is prepared by dissolving certain gums and resins in either oil, turpentine, or alcohol. In either case the

preparation dries or evaporates and leaves a smooth, solid and transparent film of resin over the surface.

A varnish is known either as an oil varnish or as a spirit varnish depending upon whether the resin is dissolved in oil or spirits of turpentine or alcohol.

Oil Varnishes.—Several different gums are used in the preparation of oil varnishes. Copal gum is most frequently used. Linseed oil is the usual vehicle for oil varnishes, with the addition of other substances to clarify it and furnish drying properties.

Spirit Varnishes.—Spirit varnishes are manufactured by dissolving the softer gums in turpentine. They dry quicker, and are lighter in color, but are not so durable as the oil varnishes. The still softer gums, such as "lac" or shellac, as it is called, are dissolved in alcohol. Shellac dries very quickly. It dries with a hard surface and a high gloss. It cracks and scales off readily and does not stand exposure.

Asphalt Varnish.—Asphalt varnish is made from asphaltum. It is a mixture of asphaltum, turpentine, and linseed oil. Common proportions for ingredients are 3 parts of asphaltum to 4 parts of boiled linseed oil with 16 parts of turpentine.

PAINTING

Quantity of Paint Required.—One gallon of linseed-oil paint should cover 500 square feet of smooth surface with one coat. This quantity will vary somewhat with the smoothness of the

TABLE 32.—COVERING CAPACITY OF PAINT

Surface	Square Feet	
Paint on siding	350	to 1 gallon
on boards	500	to 1 gallon
on steel	600	to 1 gallon
on plaster	500	to 1 gallon
on concrete	300	to 1 gallon
on brick	225	to 1 gallon
on stucco	225	to 1 gallon
Varnish on wood	200	to 1 gallon
Varnish size on plaster	300	to 1 gallon
Kalsomine on plaster	50	to 1 pound
Glue size on plaster	650	to 1 pound
Zinc sulphate on brick	100	to 1 pound
on concrete	100	to 1 pound

surface and with the porosity of it. It will also depend upon the consistency of the paint.

The covering capacity of paint on different surfaces is given in Table 32. The simplest way to arrive at the quantity of paint needed is to estimate the number of square feet in the surface to be painted. Divide this quantity by the number of square feet taken from the table. The result is the number of gallons required for one coat. If more than one coat is to be applied, add the same number of gallons for each coat.

Number of Coats.—New wood surfaces which have never been painted before should have three coats of paint. They should consist of a thin priming coat and two heavier coats.

Surfaces which have been painted before should be given two thick coats.

Metal surfaces if never painted before should be given three coats of paint on outside work. Two coats are sufficient for metal indoors.

Brick and stucco surfaces should be given three thick coats of paint containing plenty of oil.

INGREDIENTS

Exterior Paints. *Wood Surface.*—The simplest paint mix to consider is a pure white paint made with a white-lead pigment. It is assumed that the surface to be painted is an outside wood surface which has never been painted before. Three coats of paint are necessary, a priming coat and two cover coats.

The first coat applied is the priming coat. It should be mixed thin so as to penetrate into the surface.

Priming coat, quantities for 9 gallons of paint:

100 pounds of white lead
1 pint of drier
4 gallons of raw linseed oil
2 gallons of turpentine

Second coat, quantities for 6 gallons of paint:

100 pounds of white lead
1 pint of drier
1½ gallons of raw linseed oil
1½ gallons of turpentine

Third coat, quantities for 6 gallons of paint:

100 pounds of white lead
1 pint of drier
4 gallons of linseed oil
1 pint of turpentine

Interior Paints. *Wood Surface.*—The quantities given below are for a simple white-lead paint to be applied in three coats on new interior woodwork.

Priming coat, quantities for 10 gallons of paint:

100 pounds of white lead
1 pint of drier
3 gallons of linseed oil
3 gallons of flatting oil or turpentine

Second coat, quantities for 6 gallons of paint:

100 pounds of white lead
1 pint of drier
½ gallon of linseed oil
2 gallons of flatting oil or turpentine

Third coat, flat finish, quantities for 5 gallons of paint:

100 pounds white lead
3 gallons of flatting oil, or 2 gallons of turpentine

A finish coat of white paint should be given a flat or eggshell finish. To get a glossy finish a large content of oil should be used. A light paint containing considerable linseed oil will turn yellow. A glossy coat, therefore, should be avoided.

The following formula can be used for paint that is to be tinted a dark color:

Third coat, glossy finish, quantities for 6 gallons of paint:

100 pounds of white lead
1 pint of drier
3 gallons of raw linseed oil
1 quart of flatting oil, or 1 pint of turpentine

Colored Paint.—The formulas just given make a white paint. To make a paint of any other color, tinting colors are added. Tinting colors are known as "colors in oil." They may be procured in 1- or 5-pound cans. Smaller quantities may be bought in tubes. The quantity of tinting color required varies according to the depth of color wanted. For each pound of coloring matter an additional ½ pint of oil and turpentine should be added in the same proportions as already in the mix.

MIXING

Mixing the Paint.—In mixing paint sufficient white lead should be softened in a large pail with enough linseed oil to bring it to a paste.

Tinting colors should be added next if the paint is to be colored. These colors should be worked into the white lead thoroughly.

Add the drier and stir thoroughly.

Put in the remainder of the linseed oil required and stir the mixture thoroughly.

Put in the turpentine, stir thoroughly, and strain through a wire mesh or piece of cheesecloth.

The instructions given above should be followed carefully, keeping to the order of mixing. If the white lead is mixed to painting consistency before the tinting color is added, the coloring matter is likely to break into fragments which will make streaks when brushed out.

Steel Surface.—For painting a steel surface a paint containing red lead gives excellent results. It should always be used without tinting matter next to the metal. The other covering coats may be colored to give the desired appearance. One gallon of red-lead paint will cover 600 feet of steel surface.

Priming coat, quantities for 5 gallons of paint:

100 pounds of red lead
3 gallons of linseed oil

The second and third coats should be mixed in about the same proportions. If tinting colors are added, an additional portion of linseed oil should be added also.

The second and third coats may be made with a white-lead, or graphite pigment if thought desirable.

Red lead is an active drier; therefore, no drier is added with the red lead.

Red-lead paint is commonly used for the priming coat on structural steel. The specifications often call for a priming coat of red lead applied in the shop, followed by a finishing coat of graphite paint in the field after erection.

Red lead should be mixed just before using, on account of the drying action on linseed oil. The weight of red-lead pigment necessitates frequent stirring. It should be applied with round brushes.

APPLICATION OF PAINT

Weather Conditions.—The surface of the wood must be clean and dry before the priming coat is put on. Painting should never be done in damp weather. It is considered bad practice to apply paint in extremely cold weather. The temperature should preferably be above 50°F. Moisture in the wood of new buildings or on the surface will cause the greatest harm to a painting job. If there is any doubt at any time, it is best to examine the surface to see if there are any signs of moisture being present.

Preparation of Surfaces.—A wooden surface should be prepared by cleaning it of all dust and dirt and by covering all knots and resin deposits with shellac. Shellac is used to cover all spots containing pitch and to prevent discoloration of the paint. It is a comparatively cheap covering and dries almost immediately.

A steel surface should be cleaned from all dirt, loose rust, and scale before painting. The surface should be scraped where necessary and should be brushed thoroughly with a wire brush until a clean surface is exposed.

Surfaces of plaster, concrete, and brick need special treatment. They should be brushed to free them from dust and loose dirt. A plaster surface should always be given one coat of sizing before paint is applied. The object of applying the sizing is to fill all the small cracks called "fire cracks" that are usually present in a plaster surface and to kill the suction of the surface with a glazed coating. Fire cracks, if not filled with sizing, appear as dull lines on a painted surface. On painting jobs of good quality, the sizing is usually a cheap shellac sizing. Ordinary 4-pound orange shellac can be cut to 2-pound quality by the addition of denatured alcohol and will provide a quick-drying

size. Substitutes, are widely used in place of shellac. They cost about half as much as shellac. Where economy is necessary, a glue sizing may be employed. This is prepared by dissolving glue in boiling hot water. It is then applied to the plaster with a brush in the same manner as a shellac sizing.

If paint is applied to a new brick or concrete surface, the alkaline of the cement will bleach and discolor the paint. If the walls are comparatively new, they should be aged artificially by brushing on a solution of zinc sulphate. The solution should be mixed in the proportion of 3 pounds of zinc sulphate to a gallon of water. As an additional precaution for new walls, a coating of varnish or shellac sizing should be applied before painting.

Priming Coat.—After the "knotting" has been done, the priming coat is applied. This coat is an important one. It is a thin coat and is applied to fill the pores of the wood, and, at the same time, it must adhere closely to the surface so as to protect it and furnish a strong adhesive bond for the following coats. It also prevents absorption of the vehicle of the next coat. It may be seen by inspection of the formulas given that the priming coat contains a greater proportion of oil and thinner than the subsequent coats. The priming coat often is mixed with a quantity of red lead to harden it. This gives a white-lead priming coat a pink tint.

The paint of the priming coat should not be allowed merely to flow from the brush, but should be brushed well into the pores of the wood.

Puttying.—Following the application of the priming coat, all nail holes and cracks should be filled with putty. Pure putty, made of linseed oil and equal parts of white lead and whiting, should be used. All nails should be set in about 1/8 inch.

Color Coats.—The colored or finishing coats may now be applied. Each coat should be thoroughly dry and hard before the next coat is applied. Exterior work should be allowed to dry 2 or 3 days before the next coat is applied. Interior work should stand 24 hours.

Peeling, blistering, and cracking of paint are generally caused by moisture or by allowing insufficient time between coats.

Applying Paint.—There should be plenty of mixed paint on hand. If too much paint is mixed, it can be used up as under-

coats in various ways. Preferably, the painting should be started at the top and should progress downward.

Paint should always be applied by strokes of the brush parallel with the grain of the wood. The paint should be finished over by drawing the brush along the entire length of small surfaces so that there will be no breaks visible in the surface. The work should be done fast enough so that one section of a surface will not have dried before the next section is applied.

The brush should be inserted into the paint about one-third the length of the bristles. Any excess of paint should be removed by slapping the brush against the inside surface of the paint pail.

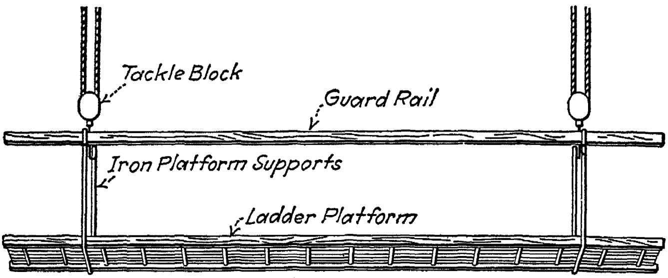


FIG. 419.—Painters' swing scaffold.

When applying the paint, only the ends of the bristles should touch the surface. The brush should be held at right angles to the surface. If the brush is held obliquely, the start of each stroke will be shown by a thick daub of paint.

Brush Work.—The round brush or pound brush, as it is sometimes called, is considered the best brush for applying a paint. Flat brushes are used for all kinds of work. They are lighter than the round brushes for the same width of stroke. Trimming or sash brushes are small. They are used for painting window sashes and small corners. These may be had in flat or round shapes. The best brushes are made of bristles. Cheaper ones are made of horsehair. They lack the elasticity, wearing quality, and paint-holding capacity of bristle brushes. Bristles can be readily distinguished from horsehair, as each bristle is split at the end into two or three parts. Horsehair is not split at the ends. A horsehair curls up when drawn through the fingers, but a bristle remains straight. The value of a brush may be gaged by the springiness of the bristles. When brushes are put in water, they lose their elasticity and become soft and flabby.

If a brush is to be used the following day, it should be suspended in paint or linseed oil.

Only a small proportion of painting work can be done by a man standing on a floor or the ground. When over head high, the painting has to be done from step ladders or scaffolding of some sort. High ceilings can be reached only from wooden scaffolds built up from the floor and extending under the entire area of the ceiling.

The sides of tall structures may be painted from an ordinary two-pole wooden scaffold, but more often a painters' swing scaffold is employed.

A painters' swing scaffold is shown in Fig. 419. As may be seen in the illustration, the swing scaffold is suspended from above

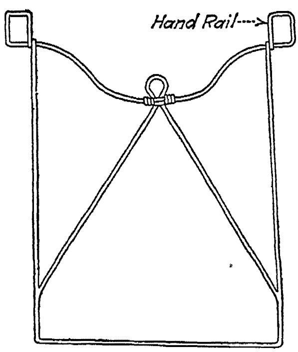


FIG. 420.—Iron platform support.

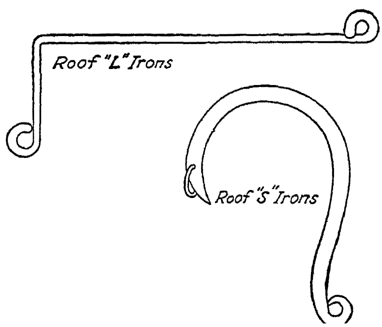


FIG. 421.—Roof irons.

by two sets of tackle. The scaffold platform consists of a ladder of special construction. Each tackle consists of one double and one single block rove with ¾-inch manila rope. The blocks have 6-inch wooden shells. The wooden platform should be hung in iron stirrups that are designed to support a wooden handrail as well as the platform (Fig. 420).

The upper tackle block is hooked into a roof iron which in turn is held by a rope which is fastened to some secure anchorage. Two varieties of roof irons are shown in Fig. 421.

Men working on the scaffold can raise or lower it easily by means of the tackle ropes. When the scaffold is stationary, the ropes of the suspension tackles can be made fast by a simple hitch, as shown in Fig. 422.

To make this hitch the rope should be snubbed under the scaffold iron, formed into a half hitch, and caught over the hook.

The free end of the rope is clamped hard up against the scaffold iron by the main part of the rope which is under a strain from the platform load. The rope is then usually taken one turn over the hook. The free end of the rope is permitted to hang from the hook. When the scaffold is to be moved, the hitch may be loosened quickly and removed.

The tackle blocks for a painters' scaffold are made with extra-long hooks which permit greater opportunity for making the rope fast.

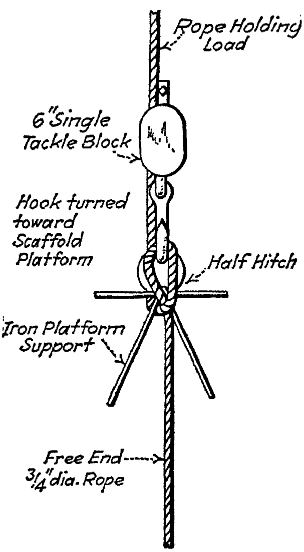


FIG. 422.—A hook hitch for painters' scaffold.

Applying Varnish.—Before any varnish is applied to any trim, the surface should be freed from dust and cleaned. All rough spots should be sand-papered smooth with No. 00 sand-paper. A filler coat of shellac should be applied, followed by the stain. Two coats of varnish should be laid on, permitting at least 24 hours to elapse between coats. The first coat, when thoroughly dry, should be rubbed down lightly with steel wool before the second coat is applied. The second coat will dry with a high gloss. It is considered desirable always to remove the gloss. This is done by rubbing down the last coat, when thoroughly dry and hard, with powdered pumice stone and crude oil. The rubbing is done with a small felt pad about the size of a man's hand. Felt rubbing pads may be procured from paint supply houses. Any pumice stone or oil remaining on the surface may be removed with a handful of cotton waste.

Graining.—When building trim made from light-colored woods, such as birch and white pine, is to be stained and grained, the procedure is as follows:

The trim should first be given a light coat of shellac to fill the pores and cover knots. A flat ground coat of light paint is then applied. After 24 hours when this coat has had time to dry, stain of the desired color is applied. While this stain is still fresh and soft, the graining is done. The man who does the

graining uses a small piece of cotton cheesecloth to wipe off the stain in streaks. These streaks imitate the grain usually seen in flat-sawed boards. When the stain is wiped off in this manner, it exposes the lighter paint below. This gives a grained appearance to the surface.

After the trim has been grained, it should be given two coats of varnish, which should be rubbed down with pumice and oil in the manner previously described.

CHAPTER XIV

CONSTRUCTION SCHEDULE

A majority of the foremost construction companies and engineering corporations execute all construction jobs undertaken by them according to a schedule or prearranged program of procedure. A construction schedule made out in the proper way is just as adaptable to one class of work as to any other. It will be found equally advantageous in the construction of a power plant or an office building.

To illustrate how a contract may be scheduled effectively, let it be assumed here, that an office building five or six stories high is about to be constructed. A schedule and a discussion of the operations involved will permit the construction of such a building to be visualized. This visualization will bring to mind the major trades which need to be employed and will serve to indicate at what period of the work each trade begins its portion of the construction and when it may be reasonably expected to have finished its work. The building in question has been assumed as of the type usually found in a majority of cities.

The sort of office building usually found in cities of the United States is a fireproof structure. The foundations are of concrete. The superstructure has a steel frame and brick walls. Partitions are of hollow tile or gypsum blocks. The floors are of reinforced concrete.

The front of such a building is commonly constructed with cut brick ornamented by belt courses and projecting cornices of stone or terra cotta.

The construction of a building of this character will usually extend over the greater portion of a year, even if the work is done strictly in accordance with a program intelligently planned in advance. If carried along in a haphazard manner, the operation might drag along for several months longer. If a contract is delayed in this manner, it will prove irritating to the owner for whom the work is being done, as well as to the company that is doing the work.

The owner is always anxious to occupy the building as soon as possible, and the contractor also is looking forward to getting the building finished and to receiving his final payment.

The only satisfactory way to insure steady and satisfactory progress on a contract of this kind is to have the work carried out in accordance with a schedule. The schedule should be outlined a week or two before any work on the contract is actually started.

A schedule is also useful in arranging for the materials that are to be incorporated into the work. It is necessary to have materials on hand when wanted. It is also very desirable that they should not be delivered too far in advance, as storage space is often difficult to provide and some supplies need to be stored in sheds or under tarpaulins. Unless care is exercised in the ordering, materials needed at the end of a job are very likely to be delivered while excavation is in progress. Materials, such as tile coping, radiators, and flag poles occupy considerable space and prove very annoying if delivered before they are needed.

BUILDING SCHEDULE

Class of work	March				April					May				June
	5	12	19	26	2	9	16	23	30	7	14	21	28	4
Excavation	—	—												
Sheeting and bracing		—	—											
Piles				—	—	—								
Foundation forms						—	—	—	—					
Foundation concrete								—	—	—				
Brick walls											—	—	—	—

It is evident, then, that a schedule decided upon before the work is begun should be prepared with two purposes in mind, that of fixing the time at which the job should be started and at which it should be completed, and also that of setting the dates at which the different items of building material may be ordered and at which deliveries should be expected.

The schedule shown here should be made out on a sheet of sufficient width to cover the entire period from the inception of operations to their completion. In the example here given, only four months are represented. There should be a space for each week, the dates given being the last day for each week. In the column headed Class of Work, each major operation should be listed. Further subdividing of each class of work is not desirable in this schedule.

As may be noted, the duration of each operation entering into the construction of the building is denoted by a heavy horizontal line.

The superintendent in charge of the contract should supplement the schedule just mentioned by another one as the job gets under way, going more into detail as to the start and finishing dates of different classes of work in various portions of the building and the number of men that will be needed to complete each operation on time.

Detailed Schedule

Class of work	Start	Finish	Remarks
Brick walls, third story.....	June 2	June 11	20 bricklayers (start partitions first story)
Brick walls, fourth story	June 11	June 20	20 bricklayers
Floor forms, second floor...	May 10	May 17	30 carpenters 5½ days
Floor forms, third floor.....	May 17	May 24	30 carpenters 5½ days
Floor concrete, second.....	May 17	May 24	20 men—5 days
Floor concrete, third.......	May 24	June 1	20 men—5 days

The schedule made out by the superintendent at the job should outline the size of organization needed. Each class of work can be separated into several smaller natural divisions. The time required for doing the work in each of these small divisions can be closely approximated, and, by studying this schedule closely, the superintendent can compute in a very simple way the number of men of each trade needed in order to keep the work up to schedule.

Referring to the schedule above, which has been assumed for illustration, it will be seen that the first column has been reserved for noting the class of work to be done. In the example assumed, the items of concrete floor forms and brick masonry walls are listed. In the first column, each item has been separated into

divisions; in the next two columns, the dates on which the work is to be started and finished should be noted.

The column under the heading, Remarks, may be used for several purposes. If any operation must wait until some other operation is completed, such a fact should be noted. For example, a note might read "Backfilling cannot be done until foundation walls are 5 days old," or any building materials that will be needed may be noted.

The Remark column will prove most useful for noting the quantity of work entailed and the number of men required to accomplish the work specified. This part of the schedule is very important, and when properly done is of great help to the man supervising the construction force.

To arrive at the correct number of men required, it is necessary to know the total quantity of work to be done, as for example, the number of cubic yards of excavation to be dug out or the number of bricks to be laid. It is also necessary to know how much each man will be likely to accomplish in a day. The number of man-days required is then readily found and the number of men required to complete the work in any interval, as, say, 10 days, can be easily calculated.

If there is any doubt as to the output of a man in a day, the estimate for the job may be consulted and the labor cost, used in pricing the contract, may be utilized to arrive at the desired information.

SCHEDULING A BUILDING

A schedule having been decided upon, the first date needed is usually easy to determine. That is the date on which the contractor arrives at the work to start actual operations. This date is usually fixed by contract requirements.

Survey.—Before any construction work is done, the correct property lines should be staked out on the ground. It is essential that the building should be built on no other property than that which belongs to the owner. If there is an encroachment of only an inch on adjacent property, the owner of that property can demand that the encroaching portion be removed, which may cause considerable expense. Local official surveyors should be called upon to stake out the correct property lines. These lines should be checked in a general way by some responsible party before any work is done. All corner points should be referenced

to other points located on the property lines extended 20 or 30 feet distant.

Excavation.—The first entry on the advance building schedule is the excavation. The time which will elapse during this operation may be quite easily approximated, if it is known by what method the excavating will be done, because the output in a day of a man, of a steam shovel, or of any machine, divided into the number of yards of excavation, will give at once the number of days required. A small allowance of time should be given for getting started and a day or so at the end for trimming and cleaning up.

Underpinning.—If there are buildings on the properties adjoining the site, it will be necessary that the excavation does not undermine the foundations of these structures. If the foundations for the new building are to be carried down to a depth below those of an adjacent building, it is necessary to carry the foundations of adjacent buildings down to the same depth.

The code of ordinances of the city of New York covering the case provides in part as follows:

> When the excavation exceeds 10 feet below the curb, the person causing such excavation to be made shall preserve and protect from injury any wall or structure which may be affected by said excavation whether such wall or structure is down more or less than 10 feet below the curb. When the excavation does not exceed 10 feet below the curb the owner of any wall or structure, the safety of which may be affected by said excavation, shall preserve and protect the same from injury.

The procedure ordinarily adopted is to excavate to the bottom of the existing foundations and then by a system of underpinning to extend them down in sections to the new level. The remainder of the excavation can then be accomplished.

Sheeting and Bracing.—If the banks of the excavation are to be supported by sheet piles and bracing, the work should be started as soon as the excavation is 7 or 8 feet deep and should continue until the excavating work is finished.

Concrete Forms.—As soon as the excavation is finished, the form work for the concrete foundations should be started. If the walls contain reinforcing rods, they can be put in place as the formwork progresses. Either of two methods may be followed on the foundation work. The quickest way is to fill any section of foundation form with concrete as soon as it can be made ready

for concreting. The cheapest way is to have all concrete formwork finished, with reinforcing rods in place, before any concrete is made. The operation of mixing and placing the concrete is then started and is continued each day until the forms are filled. The latter method is cheaper as the labor gangs are steadily employed at productive labor. With the former method, it is difficult to arrange the labor and carpenter work so that there is no loss in either class of work.

After the last piece of concrete has been poured, about two days should elapse before the concrete forms are removed. An additional day or two should be allowed to elapse for the concrete to harden before any work is placed on the walls.

During this period, if not done before, a protection should be built over the sidewalk. A fence may be built also if thought desirable.

Backfilling.—As soon as the concrete walls are 5 or 6 days old, the space between the walls and the sheeting holding the banks may be filled with backfilling and the sheeting and braces should be removed. Backfilling should be done carefully in connection with green concrete so as not to break the wall.

Steel Erection.—If the building has a steel frame, the steel erectors should arrive on the job as soon as the foundations are hard enough to stand the strains placed on them by the steel erection. The steelwork proceeds through the processes of erection of steel, plumbing of building, and riveting. The painting of the steelwork follows immediately after the riveting.

Floor Forms.—At the time the last riveting is done on the lowest floor, the building of the concrete forms for that floor may be started. Where the building is only five or six stories high, it may pay to hold back work on the floor forms until all the riveting is finished. In high buildings, the erection of steelwork and riveting is continued in the upper stories long after the time the work on the walls and floors is begun in the lower stories.

Floor forms should be left in place two weeks. The concrete is then hard enough to stand by itself and the forms can be removed, the lumber being reused on other floors above.

Concrete Floors.—As soon as the floor forms are finished, the concrete of the floors can be deposited. A portion of a floor is done each day, the size of the area depending upon the rate of progress desired. The concreting of the floors is an important part of the building operation. When the floors are concreted,

partitions can be built on them, door openings can be arranged, and the work of various other trades can proceed.

Bricklaying.—The brick walls can be started when the concrete of the first floor has been placed. The bricklaying can be held back until all the concrete floors are finished, if the building is not very high. In any case, the brick walls in any story can not be completed until the floor forms overhead are removed along the walls.

Stone Setting.—The stonework in the front of the building should be started with the brickwork so that the brick backing behind the stone may be bonded in with the brickwork of the side walls.

Other Trades.—When the carpenters start building the floor forms, several other trades should begin work. The electricians should set the electric outlet boxes in position on the floor forms and run all conduit that will be embedded in the floor concrete. The metal lathers should install the reinforcing mesh or rods for the floor slab and, also, any inserts for hanging ceilings. The plumbers and steam fitters should place sleeves in the floors for all vertical piping and install inserts for pipe hangers if they are specified.

The metal lathers, plumbers, and electricians should remain on the job from then on. The lathers will have steady work on floor reinforcing; the plumber can work on the soil stack and on other piping in the basement. The electricians can install conduit in the basement, vertical runs, and cabinets. There is plenty for them to do on conduits in the floors as the work progresses.

The work of building the floor forms continues, starting with the ground floor and working upward. The floor forms cannot be built in advance of the riveting on any floor, as they would interfere with inserting and driving the rivets. Riveting work progresses rapidly, and after a week or two the ironworkers and the steel painters depart.

During this period, the bricklayers are busy with the brick walls. The bricklayers set the window sills; the carpenters set frames, and brace them. The plumbers and steam fitters are busy with pipes in the basement and with riser pipes extending upward through the floors.

Partitions.—Tile partitions can be started on the lower floors as soon as the concrete has become hard and the floor forms above are removed. It is customary to reserve the work of building

interior partitions if possible to provide work for the men on rainy days when work on the exterior walls must be discontinued. With the building of interior partitions comes the location of door openings and erection of door bucks.

Lathing.—As soon as the first-story walls and floors and partitions are built, the walls and partitions should be covered with grounds for plaster guides and with lath so that plaster work may be started as soon as possible. The first story of a building will usually contain the greatest amount of work and will require the longest time for completion. The upper floors are usually of plain construction. It is therefore desirable to start work on the first-story walls as soon as possible, so that the first story may be completed at about the same time that the stories above it are finished.

The work in stories above the first should be scheduled from the top downward. It will be found advantageous to complete the top story ahead of the others so that the building can be cleaned out from the top downward. If this is done, it will not be necessary for the men to pass so often through rooms that are finished, tracking dirt and marking the wood trim and the finished plaster with planks or other objects that they may be carrying.

Plasterers.—With lath in place, the scratch- and brown-coat mortars may be laid on. If the building is a small one, it will be desirable to put on all the brown coats before any of the white coat is put on. Time will be saved, however, if plasterers are started on the white coat as soon as the brown coat is ready for it.

If progress on the building has been pushed energetically, the work of plastering the walls of the top story with the brown coats should follow immediately after the removal of the forms for the roof concrete. No white plaster should be laid on the ceiling or walls of the top story until the waterproof roof covering has been installed, as a leak would cause a discoloration of the plaster.

While the plastering of the brown coats is progressing the plumber forces are engaged in installing the "roughing" for the toilets, lavatories, and other plumbing fixtures. This includes small drain and waste pipes, vent piping, and water pipes. The piping is done complete with connections to risers and extended ready for installation of fixtures.

The steam-fitting crew is also busy installing branches to radiators, heating boiler, and all branch piping.

Glass should be put in all the windows and doors before the white-coat plastering is started. The first field coat of paint may be put on the outside and inside surfaces of windows.

The electricians should be busy installing service connections, panels, cabinets, and finishing all final conduit work. At this time also, all conduits should be snaked and all wires should be drawn, joined, and taped. All connections in cabinets should be made.

Before any white plastering is done, all pipework should be tested for tightness. The plumbing roughing and the steam lines and branches are equally important. The usual test is to fill the pipes with water. There will usually be a few small leaks due to defective threads, split pipes, or fittings.

At this stage of the building the work is at the peak of operation as regards number of men employed and different classes of work in progress. The force of bricklayers and plasterers should have been steadily augmented and the brick walls should have reached the roof level so that the building is completely enclosed.

The laying of brick in the parapet walls will finish the exterior walls. As part of this work, the copper counter flashing should be built into the brickwork. To cap the walls a coping of tile or concrete or stone blocks must be installed. The building is then ready for the roof work.

Before the roof covering can be applied, copper scuppers and leader heads should be installed and crickets of cinder concrete should be built to lead the water as quickly as possible over the roof surface into the conductor pipes.

It is assumed that the roof covering in this case is some system of roofing felt and asphalt. Only three or four days are required to lay an asphalt roof. A coating of waterproofing paint applied to the inside surface of the parapet walls and to the walls of all pent houses might be included in this work.

After the roof covering has been completed, the white plaster of the top-story ceiling under the roof may be started. The building is now well on the road to completion. It will simplify matters greatly if each story is completed to the last detail, following the application of the white plaster as it proceeds down through the building.

As soon as the white coat is on the walls and ceiling, the base and all trim around openings may be nailed in place. Doors may be hung and hardware installed.

The painting force should be brought up to full strength at this time. Baseboards, doors, windows, and casing must be stained, varnished, rubbed, or painted. Radiators and steam pipes must be painted. Walls, where specified, are decorated. Each operation consists of several coats.

The electricians should test and check up all wire circuits and pull in all wires not already pulled. All wiring having been proved to be correctly done, the installation of lighting fixtures is begun. At this time, the force of electricians may be decreased, as the installation of the fixtures proceeds rapidly and a large force is not required.

The white coat plaster is followed by the installation of the plumbing fixtures.

Tile setters and marble men are busily at work in different parts of the building.

The finished flooring may now be laid. This usually brings the building to a stage where it is very nearly completed.

Floors are now swept, washed clean, and oiled or waxed, as specified. The radiators are then installed and given their final coat of paint in place.

The final coat of varnish on the base should be held back until all finishing of the floors is completed, otherwise its surface would be covered with dirt and marks from the work on the floors. The base should then be varnished and rubbed down. The building should now be completed.

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